OKLAHOMA CROP PRODUCERS' WILLINGNESS-TO-PAY FOR LIVESTOCK MANURE: A CONTINGENT VALUATION APPROACH

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APPROACH

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INTRODUCTION

Reform in federal regulations is changing how producers manage manure in the agricultural industry. Structural changes occurring in the livestock production industry have resulted in many animal feeding operations over-applying manure nutrients to the land. This practice has created pollution problems in water quality and induced policy reform. Because of the people affected, the issue has become one of public debate complicated by innumerable factors. Topics often cited for problems are the geographic concentration of livestock and poultry industries, a receding interface between rural and urban societies, economic motivation for production facilities to increase in size, the economic incentive for producers to over-apply manure, and environmental degradation perceived to be a direct result of unfriendly agricultural practices.

Over the years, livestock and poultry manure has been applied to land as an organic fertilizer providing nutrients to both crops and pastures. Once the prominent source of fertilizer nutrients, animal manure was rapidly replaced with commercial fertilizers to provide precise and less costly applications of the three main crop nutrients (nitrogen, phosphorus, and potassium) needed to achieve maximum production yields. Commercial fertilizers offer several benefits over livestock manure. They provide nutrient ratios that meet the exact requirements of a specific crop; nutrient application rates are more consistent; and a less bulky fertilizer results in lower transportation costs and soil compaction from reduced field travel (Feinerman, Bosch, and Pease). As commercial fertilizer use became widespread due to its economic benefits, animal manure began to accumulate at animal feeding operations. As this movement coincided with the consolidation of animal agriculture, manure became viewed as a waste rather than a nutrient source. The livestock industry was witnessing consolidation and integration of organizations leading to larger, more regionally concentrated animal feeding operations. Producers began to specialize in single specie production and moved away from self-sufficiency, by purchasing feed rather than growing feed crops. The need for cropland was reduced causing livestock producers to own fewer acres of land and animal units per acre to rise. Because the demand for livestock manure has declined and the cost to transport manure nutrients long distances exceeds the economic benefits of manure nutrients, producers have an incentive to apply nutrients to fields at rates exceeding the nutrient requirements of the crop or pasture. As manure is over-applied, excess nutrient levels build up in the soils and leach into to surface and ground waters, adversely affecting water quality.

The Environmental Protection Agency (EPA) estimates that 20% of all U.S. water quality problems involve agriculture. This evident abuse by producers over-applying manure nutrients has induced numerous policy changes supported by environmentalists, governments, and the general public. As a result, governmental regulations on animal feeding operations are increasing. For many operations, the regulations increase costs and reduce profitability. Revisions made to the 1972 Clean Water Act are forcing many livestock operations to seek off-farm acres for manure removal. As operations seek to become compliant by the end of 2006, numerous articles note that compliance costs for livestock operations depend on the distance manure must be transported and the willingness of crop producers to pay for manure. Therefore, determining the willingness-to-pay (WTP) of crop producers will be the primary component for estimating total cost of the policy.

Currently, crop producers' willingness-to-pay has not been estimated. To determine WTP, a number of crop producer factors must be measured to determine their effects on WTP. Some of the factors include the specific type of animal manure, types of crops and livestock managed, previous crop producer experience with spreading manure, whether the manure is in solid or liquid form, and how the manure is applied (topical or subsurface application). Better understanding the significance of these factors will assist in identifying specific manure attributes preferred by crop producers. The primary research question will be, "What is Oklahoma crop producers' willingness-to-pay for livestock manure?" Secondly, "What is the distribution of crop producers' willingness-to-pay?"

Livestock Manure Applications and Negative Externalities

Animal agriculture's restructuring has prompted the production of more meat at a lower cost. However, many adverse consequences are the result of this industrialization. The primary issue related to the livestock industry is the proliferation of confined animal feeding operations[1] and the subsequent manure management issues. As the livestock industries have become regionally concentrated, so too have the feed grain nutrients used to grow these animals. Concentrating facilities and decreasing the number of acres per animal unit increases the probability that excess nutrients will leach from the soil and

[1] Confined animal feeding operations (CAFOs) are feeding operations that have more than 1,000 animal units at a specific location. Operations with fewer than 1,000 animal units can be defined as a CAFO for other reasons defined by the Environmental Protection Agency.

enter ground or surface water. Mullen and Centner note that 90% of manure does not leave the geographic area in which it is produced. The reason many of these nutrients remain on-site after harvesting the animals is because removal of the nutrients is expensive. This often promotes applying manure at rates higher than what the crop or forage can use in a growing season. The problem is not finding available land, as much of the nation has adequate land for spreading manure in safe amounts. Rather, the cost of transporting manure exceeds the nutrient value. Manure is valuable as both a fertilizer and a soil conditioner, but its low market value and cost to transport mitigates any benefit, motivating producers to seek the least cost disposal method and over-apply. Reasons for low market value of manure include the bulkiness of the product that incurs additional transportation costs and soil compaction, varying nutrient content, and other potential contaminants such as disease and weeds (Alberta Government).

The industrialization and regionalization of the livestock industries has brought more attention to livestock pollution because of the increased potential for environmental degradation. A publication by the USDA, released in December of 2000, provides perspective about the seriousness of nutrient overloading and the potential for water pollution. Kellogg et al. focus on the increasing frequency of manure loading on land in the immediate proximity of confined animal feeding operations (CAFO). As stated earlier, the cost of hauling manure only a short distance can exceed its economic benefit. This causes much of the cropland surrounding a CAFO to receive manure nutrients far exceeding the assimilative capacity of a crop during the growing season. If manure is not exported, the opportunity for nutrient buildup and subsequent runoff greatly increases as rates exceed crop demands. If the probability of pollution does increase with farm size, then there is great need for concern. In 1997, 48.6% of the confined animal units in the U.S. were on farms that could qualify as CAFOs (Kellogg et al.). This suggests that many of the operations are faced with increasing animal units per acre and land constraints that may provide incentive for many operations to over-apply nutrients.

Taking a closer look at excess nutrients, the study estimates the number of counties across the nation in which manure nutrients from livestock operations exceed the respective county's assimilative capacity. Assuming land application of manure is the only fertilization technology in practice and all county pasture and cropland is available for manure spreading, 73 counties in the U.S. have excess manure nitrogen[2] and 160 counties have excess manure phosphorus[3]. This is despite the fact that the USDA admits that transporting some manure nutrients across a county for application is impractical. Figure 1 demonstrates the trend of increasing quantities of excess nutrients for both nitrogen and phosphorus at potential CAFOs from 1982 to 1997. Furthermore, since 1982, the percentage of counties with excess nitrogen and phosphorus increased by 103% and 57 %, respectively. This suggests that consolidation and deteriorating waste management practices are becoming more widespread and leading to excess nutrients that are known contributors to water pollution.

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[2] Defined as the imbalance between the nitrogen assimilative capacity of the cropland and the quantity of manure nitrogen produced in the county.
[3] Defined as the imbalance between the phosphorus assimilative capacity of the cropland and the quantity of manure phosphorus produced in the county.

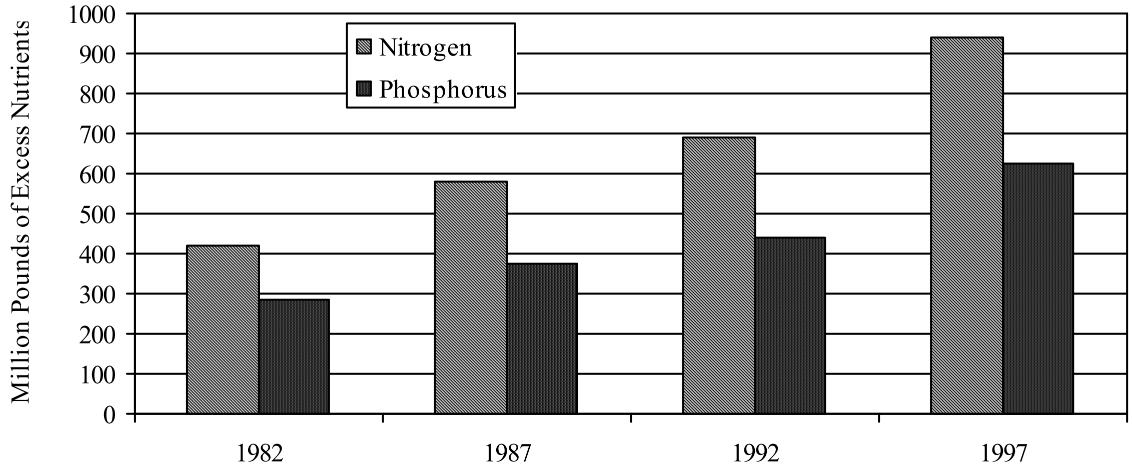

Figure 1. Excess Manure Nutrients for Potential CAFOs
Source: Kellogg et al.

Once nutrients enter the water system, the externalities they create can take years to correct. In some cases, complete bio-systems are destroyed in a few weeks. The Unified National Strategy for Animal Feeding Operations (UNSAFO), written by the USDA and EPA, documents that agriculture is the most widespread source of pollution in the nation's surveyed rivers. Manure nutrients (nitrogen and phosphorus) and potentially heavy metals, pathogens, hormones, antibiotics and ammonia, reaching bodies of water, are known contributors to the eutrophication[4] of water and associated with bacterial outbreaks. Examples of serious water quality impairment have brought many waste management issues to the attention of policymakers. This has resulted in policy changes that are the foundation for discussion later in this document.

One such water quality incident was the cryptosporidium outbreak in Milwaukee, Wisconsin's drinking water that sickened more than 400,000 and caused the death of 104 people. It was believed that livestock waste was a contributor to the problem. In 1995, one and a half million gallons of raw hog manure contaminated the South Fork of the

[4] Eutrophication is when an abundance of nutrients promote excessive algae growth in water. Rapid algae growth depletes the available oxygen in water, creating fish kills and odorous drinking water.

Iowa River. In another instance, 25 million gallons of swine waste overflowed from a lagoon in North Carolina. To put the spill into perspective, that is twice the amount of the Exxon-Valdez oil spill (Innes).

Oklahoma has struggled with its own water quality issues. Since legislation in 1991 that paved the way for corporate farms in Oklahoma, the state has seen a proliferation in swine production. From 1991 to 2000, the number of swine in production increased from 190,000 to approximately 2.26 million (OWRB). Many of these operations are located in northwestern Oklahoma alongside cattle feedlots and pose a contamination risk to underground water supplies such as the Ogallala aquifer. If high levels of nitrates contaminate the water, the entire water supply can be deemed unsafe to drink (Lazo et al.).

Likewise, many scenic rivers in eastern Oklahoma do not meet water quality standards due to the application of chicken litter to surrounding agricultural land. For example, the eutrophication of Lakes Eucha and Spavinaw in eastern Oklahoma has been blamed on the over-application of chicken litter to land in the watershed. This forces the City of Tulsa to use expensive water treatment practices to remove the bad taste and meet water quality requirements (Ancev, Stoecker, and Storm). Currently, poultry producers are anticipating action from the Oklahoma attorney general that could further restrict or prohibit the application of all poultry manure (Previch). In the next section, the researcher discusses the industrial changes influencing the waste management dilemma.

Industrialization and the Influence on Policy

As part of American agriculture's industrialization, the past 30 years have brought about remarkable changes in the demographics and structure of animal agriculture. What was once a diverse industry, characterized by small numbers of numerous types of livestock, has become specific operations specializing in the production of thousands of animals (Bottomline Statistics). As animal numbers have increased at facilities, production cost advantages have increased due to the specialization and repetition of tasks (Norris and Thurow).

Facilities have migrated to a regional location specific to one industry to take advantage of feed sources, climatic conditions, corporate incentives and proximity to market outlets. For example, 80% of the cattle raised in feedlots are concentrated in Texas, Kansas, Nebraska, and Colorado; broilers are largely produced in the South, specifically Arkansas, Alabama, and Georgia; the swine industry has been primarily in the Midwest until the proliferation of operations in North Carolina and to a lesser degree Oklahoma (Bottomline Statistics).

Collectively, animal agriculture has changed from a land-based activity to a specialized capital-intensive activity focused on profit maximization and cost minimization (Abdalla, Lanyon, and Hallberg). The trend toward consolidation, vertical integration, and geographic concentration began with the poultry industry in the 1960s and 1970s. Similarly, from 1966 to 1996, the number of swine operations dropped from one million to less than 160,000 while the number of animals remained at approximately 57 million. Further, in 1996, fewer than 5,000 swine operations accounted for more than 50% of the entire nation's swine production (Bottomline Statistics).

These changes in the swine industry over the past twenty years have not gone unnoticed by the public and policymakers. Concerns about large hog operations, including environmental degradation, offensive odors, and economic displacement from a relocating industry are greater than those for previous developments in other animal sectors. This public awareness has raised the visibility of issues, increased the intensity of public debate, and generated pressures for policy change applicable to all livestock operations. After discussing industry changes over the previous 40 years, the next discussion explains how regulations and policy may influence future industry changes.

Manure Management Regulations

The Clean Water Act of 1972 serves as the centerpiece for water quality protection. Since implementation, the EPA has been regulating animal feeding operations. Despite efforts to curb pollution, contamination of water from nitrogen and phosphorus remains to be a major problem and the primary reason for regulations. A large percentage of the livestock industry's transition did not occur until after the Clean Water Act, thus many rules were not written with consideration for the structural changes that have taken place in the industry. Since that time, the industry has become a collection of large, geographically concentrated operations. As a result, manure pollutants have received greater attention from state and federal agencies. This has brought about numerous instruments, policies, and regulations addressing unforeseen problems in the original Clean Water Act.

In 1999, the UNSAFO cited growing environmental and public health issues and the need to address them. The UNSAFO identifies seven strategic issues to be addressed to improve issues related to animal feeding operations. They are (1) fostering CNMP (Comprehensive Nutrient Management Plan) development and implementation; (2) accelerating voluntary, incentive-based programs; (3) implementing and improving the existing regulatory program; (4) coordinating research, technical innovation, compliance assistance, and technology transfer; (5) encouraging industry leadership; (6) increasing data coordination; and (7) establishing better performance measures and greater accountability (Federal Register).

As part of the Strategy's objective to reduce water pollution from AFOs, the USDA and EPA encouraged all animal feeding operations to develop CNMPs. The plans should address feed management, manure handling and storage, land application of manure, land management, record keeping, and management of other utilization options. Additionally, the CNMPs should identify a plan to implement the management practices and be specific to the location and goals of the operation and producer (USDA, USEPA). Despite the recommendations, few producers went forward and implemented the plans due to the costs associated with developing a plan.

These recommendations were in foresight to a planned reform of the Clean Water Act. In 2003, the EPA unveiled rules in the Clean Water Act requiring all CAFOs to meet nutrient application standards as defined in a CNMP and acquire a NPDES (National Pollutant Discharge Elimination System) permit (Ribaudo et al.). This focuses on making sure that manure application is consistent with crop uptake. Under these plans, producers are expected to make a number of manure management improvements that can increase production costs. The Unified National Strategy suggests that producers modify animal diets to reduce unused nutrients in the manure; manure handling should prevent water pollution and consider odor and other environmental problems; manure should be managed to prevent nutrient loss to the atmosphere; producers should keep detailed records of the quantity of manure produced and where, when, and how many nutrients are applied to a field; records should also include soil and manure testing; and movement of organic materials, nutrients, and pathogens should be minimized by buffer strips to utilize nutrients or other undesired amenities moving from the application site (USDA, USEPA). The magnitude of these requirements creates incredible costs. In the EPA's final rule on CAFOs (hereafter CAFO rule), they estimated that these regulations would cost CAFOs $283 million dollars a year. In addition, more than 285 CAFOs may be susceptible to facility closure due to their limited access to land needed for proper manure disposal (Federal Register).

The major logistical problem this creates for many producers is the possibility of land constraints to adequately spread manure. With the CAFO rule, the EPA is requiring large CAFOs to determine the potential for nitrogen and phosphorus loss on all fields that will receive manure, litter, or lagoon effluent (Sheffield and Paschold). Law requires that a soil assessment be determined before manure is applied to a field. The level of nutrients already present in the soil then determines how producers are allowed to spread the manure. Historically, livestock producers have applied manure to crops on a nitrogen basis. This means that manure can be applied at a rate to satisfy nitrogen requirements for the crop. However, the problem arises that animal manure contains an excessive amount of phosphorus when manure is applied on nitrogen basis. In general, crops require only one part of phosphorus to about eight parts of nitrogen (Zhang, Johnson, and Raun). Thus, as producers apply manure on a nitrogen basis, phosphorus is being over-applied resulting in phosphorus loading of the soils and subsequent erosion of phosphorus rich soil particles into freshwater supplies.

This scenario damages the quality of upstream and fresh waters. In waters such as those common to Oklahoma, phosphorus is the limiting nutrient, and when phosphorus leaches into water with abundant nitrogen, a proliferation of microorganism growth occurs resulting in eutrophication (Norwood and Chvosta). As a result, this CAFO rule places a larger emphasis on phosphorus-based plans for large CAFOs. To assist producers, enforcement officials, and development professionals, a phosphorus index has been developed to asses the potential for nitrogen and phosphorus movement under different land characteristics and management practices. The index tool identifies areas that may exhibit a greater risk for phosphorus movement, relative to other sites. The index is based on eight characteristics that aid a producer in assigning a numerical value to each of the characteristics. The characteristics include factors for soil erosion, irrigation erosion, soil runoff class, soil test phosphorus, rate of commercial fertilizer application, method of commercial fertilizer application, rate of manure phosphorus application, and method of manure phosphorus application. After determining a site rating, one can assess the possibility of any adverse phosphorus impact to water resources. On lands where the phosphorus index rating is determined to be low or medium, manure may be applied on a nitrogen-based application as discussed previously. For lands considered high to very high risks, manure must be applied under a phosphorus-based plan or not at all (NRCS).

When phosphorus-based applications are implemented, these production restrictions become a greater issue to producers by forcing many to seek off-farm acres for manure disposal. For instance, consider moving from a nitrogen-based plan to a phosphorus-based plan. The effective land base required to spread manure could increase by eight, because instead of applying eight units of manure to a crop, one can only apply one unit[5]. Consider a study by Norwood, Massey, and Zhang revealing that 40% of Oklahoma surveyed swine producers were already land constrained prior to the implementation of the CAFO rule. Farm level analysis of hog and dairy CAFOs suggests that production costs could increase by two under a phosphorus-based standard. As phosphorus-based standards become practice, many producers must seek off-farm acres to comply. Thus, operations forced to export manure will face the largest compliance costs of regulations. To estimate these costs, the crop producers' willingness-to-pay must be defined. The next section identifies the components needed to identify the WTP of livestock producers and examples of inadequate research on the topic.

Willingness-to-Pay: The Missing Link in Compliance Costs

Complying with the CAFO rule requires CAFOs to spread their manure over a much larger land base than they are using, and most will need to move manure off the farm. Although these regulations only focus on CAFOs, they make up about 5% of animal feeding operations, contain 50% of all animals, and produce over 65% of the excess nutrients (Ribaudo et al.). For many operations, the impacts of these regulations could reduce profits. Therefore, it is imperative that a cost assessment can be determined for this large group of producers.

[5] Recall that earlier Zhang, Johnson, and Raun noted the nitrogen – phosphorus ratio required by most crops is eight – one.

Estimating these costs requires assumptions surrounding farm types, nutrients generated in manure, transportation costs, cropland surrounding the farm, and the willingness of surrounding crop producers to accept manure. Numerous studies focus on estimating compliance costs for livestock operations, but none focus on the willingness-to-pay of crop producers for manure. Ribaudo et al. note that livestock and poultry farms' annual net income could decline by more than one billion dollars, but the precise outcome depends greatly on the extent to which cropland operators are willing to substitute manure for commercial fertilizer. As more cropland operators are willing to take manure, the net costs of hauling manure decrease. In their study, they analyze the regional impact for animal feeding operations. For CAFOs in Oklahoma, the net cost per animal unit under a nitrogen standard regardless of crop producer acceptance rates. However, a phosphorus standard finds that net costs per animal unit per year can be as high as $27 when only 10% of producers will accept manure. This falls to approximately $10 if 80% of producers are accepting (Ribaudo et al.). The problem that this study fails to address is that costs of $10 per animal unit may be manageable, whereas $27 per animal unit could force an operation to cut production entirely. Because a specific level of acceptance for crop producers is not identified, an accurate estimate of compliance cost is still unattainable.

Other studies by Metcalfe et al. and Glewen and Koelsch attempt to gather information about the prices livestock producers receive for applying manure on crops. Both studies identify transactions where livestock producers receive compensation for the manure, but because of the relatively small sample sizes, what little information the studies did reveal could not be statistically validated.

Another study by Feinerman, Bosch, and Pease exhibited a deficiency in acceptance rates. They attempted to determine the value of manure based on the cost to apply, handle, and transport the manure to cropland. However, if transport cost is dependent on the distance manure must be hauled, one cannot estimate the compliance cost to an operation without speculating on the acceptance of local crop producers.

These deficiencies in crop producers' acceptance rates is evidence of the need to determine crop producers' willingness-to-pay[6] for livestock manure. By determining the value at which producers will accept manure, the researcher can provide more accurate compliance costs estimates. Therefore, the general objective of the study is to reveal information leading to the reduction of animal feeding operations' compliance costs from waste management regulations requiring off-farm exportation of manure. Specifically, the study will seek to satisfy two objectives: (1) Determine the correlation of crop producers' willingness-to-pay with manure attributes and producer demographics, and (2) Identify the willingness-to-pay distribution of Oklahoma crop producers.

With this information, one can better estimate the land availability to livestock producers by determining crop producers' preferential characteristics of manure products. Not only will a producer be better informed about the potential costs and land availability for application, but a livestock producer may also adapt his or her products to consumer demands to encourage the adoption of manure fertilizers. Additionally, this information will be useful to policymakers in achieving the objectives of the Clean Water Act revisions and the Unified National Strategy by designing policy that fosters the movement of manure from areas of higher to lower concentration.

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[6] Willingness-to-pay allows the researcher to measure the value of manure to a crop producer. One can then interpret willingness-to-accept manure as the percent of producers willing-to-pay $0.

LITERATURE REVIEW

The federal government has regulated waste discharged from confined animal feeding operations (CAFOs) since 1972. Research about manure management issues has expanded considerably to address this continually growing problem. When the Clean Water Act's National Pollution Discharge Elimination System (NPDES) permit program designated farms with 1,000 or more animal units (CAFOs) as "point sources" of pollution (Ogishi, Metcalfe, and Zilberman), the move prompted agricultural extension specialists and academics to provide policymakers, livestock and poultry producers, and other agriculturalists with information highlighting the concerns of animal waste in the environment. Although manure management received attention at a national level, the general public did not become informed until the last ten years about the environmental amenities that many agricultural practices threaten. As a result, agriculture has witnessed increased public scrutiny and regulatory actions attempting to increase environmental quality.

The policy greatly impacting the agricultural industry is the Clean Water Act revisions implemented in 2003. The potential consequences that these regulations could create in the meat production industry have motivated numerous studies to determine the effects to the agricultural industry. These regulations could force many livestock producers to greatly increase the land area on which they apply animal manure. This may force many livestock producers to seek off-farm acres and obtain crop producers' permission to spread animal waste. For many livestock operations, the willingness-to-pay (WTP) of crop producers for livestock manure will largely determine the cost of compliance. If livestock producers can establish a viable market for manure, this will aid producers in countering the costs incurred to bring facilities within compliance. As a result, this study seeks to determine demand for swine and poultry manure by eliciting crop producers' WTP. The remainder of this chapter consists of two sections. The first includes two parts discussing previous policy ineffectiveness and the absence of specific compliance cost estimates for livestock producers implementing nutrient management plans. The second section focuses on non-market valuation procedures, particularly contingent valuation. A theoretical discussion of the valuation method and corrective procedures to increase reliability of the contingent valuation estimation procedure is included.

Policy Design Failures

Many critics of manure management policy argue that regulations including the NPDES program are ineffective in preserving water quality because only a fraction of all animal feeding operations are regulated (those being mostly CAFOs). With the rule, the Environmental Protection Agency encourages state agencies to use voluntary and incentive programs to help medium and small sized operations prevent actions that would subject them to the rule (Goan). Norris and Batie, citing a survey of waste management facilities in North Carolina, indicate that smaller, older swine operations that fall outside federal regulation are more likely to be repetitive sources of pollution that large CAFOs.

One reason for failed policy is the lack of enforcement officials and a specific regulating agency. Many local and state agencies responsible for setting standards and regulations do not have the legal power to pursue violations (Mullen and Centner). Because lame-duck jurisdiction leaves many organizations incapacitated to act, disciplinary action must be carried out by a more authoritative agency that understands less about the problem and may be unwilling to pursue litigation. Mullen and Centner continue to note that production operations will seek to minimize their costs. Therefore, many livestock operations consider the risks between regulatory compliance and the potential penalties if cited for violations. Increasing the number of regulated firms has little beneficial impact on the environment if facilities continue to escape compliance due to a short supply of enforcement officials. In fact, because of incredibly high compliance costs, it may be cheaper for a firm to prolong the time between compliance and avoid the high costs in exchange for the risk of being cited for violations. Moreover, past precedents by enforcing agencies suggests that consequences from violations may be minimal given that agencies are likely deficient in definition, personnel, and funding to inclusively pursue all violators (Mullen and Centner).

Norris and Thurow cite several instances where regulation does not achieve its designed purpose. The responsibility of administering CAFO permits has been assigned to many state environmental agencies. Yet, the interpretation of CAFO permissibility for each state allows for a lack of uniformity across state lines and creates even greater difficulty when disputes involve multiple states. One such case is the expensive water treatment practices implemented by the City of Tulsa. Livestock facilities in both Arkansas and Oklahoma contribute to the eutrophication of the Eucha-Spavinaw watershed and the subsequent expensive water treatment practices (Ancev, Stoecker, and Storm). However, the lack of a universal policy severely inhibits the City of Tulsa's ability to hold Arkansas producers liable for increased processing costs to remove odors.

An example of these problems is an account of filed complaints in the State of Oklahoma about pollution problems at livestock facilities. During a four-year period, 285 complaints were filed, and only 20 of those complaints were ruled upon. 15 were ruled to not be violations of the law and only five were proven to be violations (Frey, Hopper, and Fredregill). Therefore, the other 265 complaints went unresolved, leaving one to believe that no corrective action was taken in response to the complaints. This is a clear indication of the perplexity regulators, agricultural producers, and citizens face to reach common ground that satisfies the public, is easy for regulators to enforce, and leaves producers with realistic regulations.

Policy instruments may commonly send the wrong signals to policymakers. Currently, water quality is the only legal tool that allows for enforceable action under federal law (Norris and Batie). As a result, neighbors disgruntled with CAFOs or other nuisances such as odor or flies cite water quality issues as a means for legal action. Thus, attempts by policy or production operations to correct the cited problem may be in response to the wrong stimuli, because the underlying nuisance bringing about the legal suit may not be easily measured (i.e. odor, flies, loss of property value, etc.) (Norris and Thurow).

Regulations written prior to agriculture's large industrialization movement are another problem often cited. In many cases, the organizational structure and the common practices of contracting, geographical consolidation of feeding operations, and the concentration of manure nutrients were not considered when policy tools were originally designed (Ogishi, Metcalfe, and Zilberman). This allows many gaps and loopholes in the regulations. For example, political motivation to protect small "family farms" allows many operations to avoid regulatory compliance when in fact they too, in an aggregate sense, significantly affect environmental quality despite low production levels (Ogishi, Metcalfe and Zilberman). As a result, these regulatory deficiencies allow unregulated producers to employ insufficient waste management practices in regard to federal regulation.

Innes argues that regulating observable producer choices would allow the government to induce producer behavior that accounts for its environmental externalities. By using economic theory and market forces, policy can provide the proper incentives for operations to follow government regulatory objectives and policies. Regulated production decisions could include regulating a maximum number of animal units per acre of land, stricter specifications for which lagoons must comply to protect against storm overflows, or encouraging more regional concentration of facilities to decrease the potential of widespread pollution and make producers' practices more assessable to regulators (Innes). Ogishi, Metcalfe, and Zilberman suggest establishing marketable permits for producing animals or, more directly, pollution permits similar to the manufacturing industries' permits to pollute.

Waste management and pollution issues are abundant. Prior to the concentration of production facilities, many of the issues were of little concern primarily because they were less observed by society. As livestock and poultry industries have transformed and consolidated, numerous problems have emerged and/or become magnified under society's watchful eye. Public relation catastrophes such as the lagoon spill in North Carolina that dumped 25 million gallons of hog waste into the New River and the potential link between dairy manure runoff and the Milwaukee cryptosporidium outbreak in drinking water that sickened more than 400,000 and killed 104 people has done nothing to reduce public scrutiny (Innes). Because of these and other events, policy and regulation are attempting to improve agriculture's practices and decrease some of the social costs linked to livestock production.

Clean Water Act Regulations

In a continuing effort to address these issues and many others, rules in the Clean Water Act, defined by the EPA in 2003, require concentrated animal feeding operations to meet nutrient application standards as defined in a nutrient management plan (Ribaudo et al.). The Unified National Strategy for Animal Feeding Operations strongly encourages each animal feeding operation to "develop and implement a technically sound, economically feasible, and site-specific" comprehensive nutrient management plan (CNMP) for properly managing manure produced at the facility (CAFOs are required to develop a CNMP by law) (USDA, USEPA).

For many producers, animals at the facility produce more manure nutrients than can be applied to the surrounding land without accumulating excess manure nutrients in the soil (Kellogg et al.). Under the requirements of the nutrient management plans, many larger livestock operations do not have adequate land access to spread their manure within compliance limits. A study by Kellogg et al. found that in 1997, of the 11,242 potential CAFOs, 2,603 operations had no acres of pastureland or the 24 crops identified in the study on which to spread manure. This implies that nearly one-fourth of the CAFO operations will have to rely solely on manure exportation. Of these without any land for spreading, 41% was made up of poultry and 38% of swine operations (Figure 2.). Thus, swine and poultry industries may be the hardest hit with compliance costs. Because these operations and many others realize restricted land access, many livestock operations must seek out land under the control or ownership of crop producers to apply within specific rates determined by the livestock operations' CNMP. More alarming to livestock producers facing regulations is a study by Ribaudo, Cattaneo, and Agapoff. They note that the acreage required by swine CAFOs under a phosphorus-based spreading strategy in Colorado, Oklahoma, and Utah would far exceed the available land area.

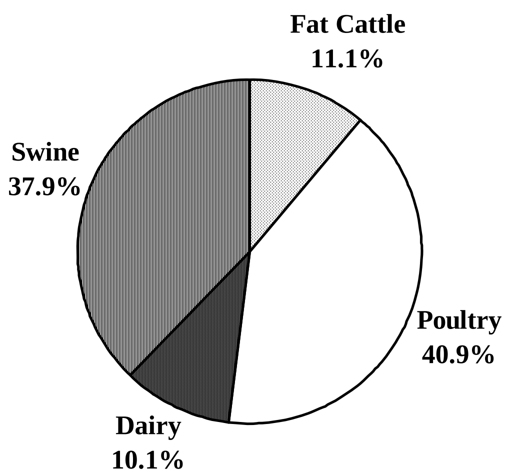

Figure 2. Industry Percent of All CAFOs without Crop or Pastureland
Source: Ribaudo et al., 1997 data.

Excess manure nutrients create many problems for producers. The primary problem is that exporting excess manure from their facility creates additional costs. Many other factors influence the potential costs. Ribaudo notes that complying operations incur added costs for developing a CNMP: testing manure for nutrients, hauling manure longer distances, and applying manure to more land. However, one should note that CAFOs are already required by law to have a CNMP (Ribaudo et al.). Therefore, the largest compliance cost to be felt throughout the industry is expected to be the cost of seeking additional land and the resulting manure application costs.

As Fleming, Babcock, and Wang found, the distance manure must be hauled and its nutrient content are the two most important factors affecting the potential benefits to crop production. They found that commercial fertilizer cost savings were most significant when manure storage systems promoted maximizing the manure nutrients retained (i.e. anaerobic lagoons promote the release of nitrogen into the atmosphere along with other gases). Thus, manure treated under an anaerobic lagoon system resulted in off-site transportation costs exceeding the nutrient value of the manure due to its lack of nitrogen. One should note that the majority of Oklahoma swine operations operate anaerobic lagoon systems. For many producers, this may be a disadvantage due to the decreased ratio of nitrogen to phosphorus.

One overriding concern that Fleming, Babcock and Wang note is that despite the manure management control options, such as phosphorus-based application versus nitrogen-based, incorporation versus surface application, or storage/nutrient conservation decisions, production decisions in the swine industry are solely driven by the market value of the hog. However, because regulations threaten the financial stability of some operations, traditional decision rationale may need to be altered to increase environmental quality and decrease nutrient runoff and contamination.

Feinerman, Bosch, and Pease note several obstacles manure must overcome before it becomes a widespread commercial fertilizer substitute. For manure to become more competitive with commercial fertilizer, the nitrogen to phosphorus ratio must be increased to a level that better meets the nutrient requirements of crops. They further note that farmers' acceptance of manure will depend on the manure's relative cost to commercial fertilizer. As spreading livestock manure falls under greater regulation, producer demand may decrease because additional transaction costs incurred by a producer to understand and follow regulations do not offset the economic benefits. The next section discusses the absence of these cost estimates and the need to identify them.

Regulated Livestock Producers Lack Specific Compliance Estimates

The Clean Water Act's regulations are forcing many livestock operations to become compliant for the first time. For many, the impacts of the regulations could decrease an operation's financial stability. A joint report by the Economic Research Service and United States Department of Agriculture, discussing costs to AFOs applying manure, indicates that if manure acceptance by crop producers remains at low levels (approximately 20%), production across all animal feeding operations could decline by as much as 27% in broilers, 12% in fed beef, and 6% in pork (Ribaudo et al.). Similarly, evidence from Kaplan, Johansson, and Peters suggests regulations on manure nutrients will reduce livestock production and subsequently increase meat product prices.

Because of the potentially large effects to both producers and industry, Ribaudo et al. attempts to more thoroughly estimate the impacts of the Clean Water Act regulations by shedding light on manure distribution and management costs. However, the report fails to measure the percentage of producers willing to accept manure. Instead, the report hypothetically analyzes the impacts of varying producer acceptance rates. Thus, the true estimated compliance costs to livestock producers remain unquantifiable because little has been revealed about the crop producers' actual manure purchasing behaviors. Absent these integral components of research, determining the distance that a producer can expect to haul manure and the compensation that she could receive is reduced to a best guess estimation. Therefore, the absence of specific cost estimates provides little information to the livestock producer.

One reason for the lack of precision is that many assumptions must be made about crop and livestock producers' behaviors. Ribaudo states in a USDA-ERS publication that the total compliance cost to an average swine operation in the mid-Atlantic region with more than 2,500 animals could range from $1,450 to $32,500 per year depending on the willingness of local landowners to accept manure. Livestock operators likely to see the greatest increase in cost are those forced to seek off-farm acres to effectively remove the manure from their operation. Although helpful, providing a cost estimation with a variance this large does little to help management pinpoint costs and determine the appropriate management decisions.

For livestock producers to have a better estimate of compliance costs, the willingness of local crop producers to accept manure must be determined. One study determining the opportunity for feeding operations to remove manure is a manure marketing survey conducted by Glewen and Koelsch in 1998 on 210 Nebraska feedlots. The survey asks feedlot owners to disclose their financial arrangements for manure removal. Feedlots with 1,000 or fewer animal units generally have adequate land to apply manure under both nitrogen and phosphorus plans. Medium sized farms (between 1,000 and 10,000 animal units) have enough land to only use all of the nitrogen nutrients. However, the largest feedlots lack adequate land to completely use all of the nitrogen or phosphorus nutrients. Of the largest feedlots, 80% indicated they exported manure (Glewen and Koelsch).

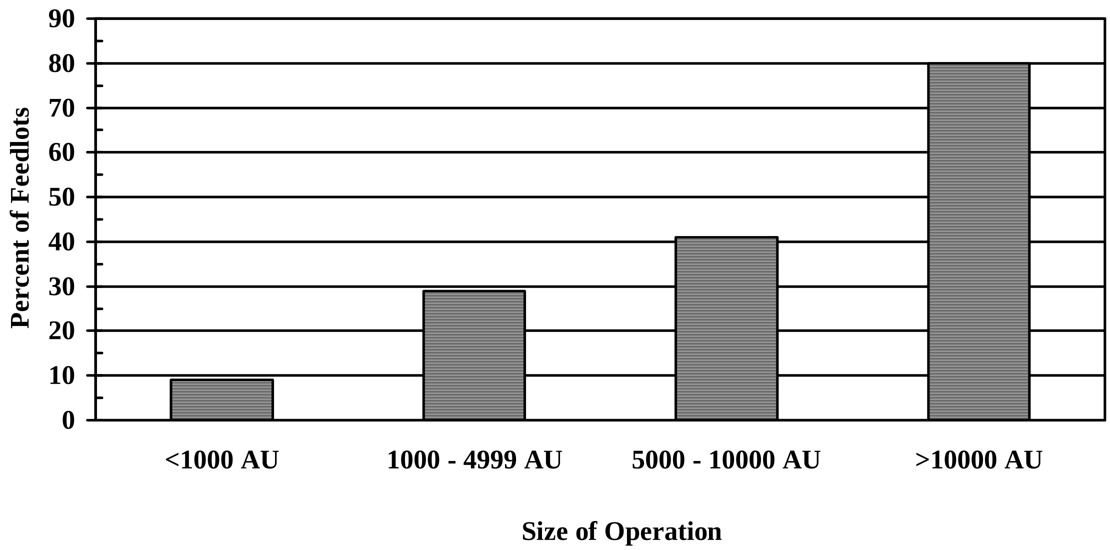

Figure 3. Categorical Percent of Feedlots Exporting Manure
Source: Glewen and Koelsch. "Marketing Manure"

A commonality discovered between all manure exporters, despite operation size, was their animal density exceeded 30 animal units per acre of cropland. Maybe more indicative of the situation is the fact that producers who did not have to export manure average only seven animal units per acre of cropland (Glewen and Koelsch). Smaller operations are more likely to maintain a lower animal density, and therefore rely less on manure export as a means to remove manure nutrients.

Producers indicate that the most common financial arrangement for a feedlot's manure removal is to give manure away at no charge (54%) (Glewen and Koelsch). An important observation from this survey is that often the livestock operator is responsible for the transportation of manure. This may indicate that the livestock producer will be disadvantaged when negotiating a price. Crop producers realize the limitations of livestock operations and are less flexible in negotiations. Another downfall contrary to the benefits of organic material and crop nutrients in manure are crop producers' focus on the potential for soil pathogens, the lack of uniformity in nutrient content, variation in application rate, soil compaction, and the lengthened release time for nitrogen in manure when compared to chemical fertilizer (Wortmann).

Few producers realize the marketing potential of manure as a fertilizer alternative. Research suggests that livestock producers may underestimate the value of their manure. Glewen and Koelsch found that more than 30% of feedlots receive a price exceeding $0 for manure application. Metcalfe et al. reveals somewhat contrasting indicators in a late 1990s study that evaluates the production practices of Oklahoma swine producers and federal regulation affecting them. The survey of the swine producers finds that over-application of manure is often attributed to two factors: land access constraints and manure transportation costs. As operations have grown in size, the cropland retained by the operations has not increased proportionately. Thus, manure production increases, costs of handling manure begin to exceed the economical benefit of application, and the nutrients become concentrated in one area leading to potential runoff.

Many producers also struggle to receive compensation for their manure. This is evident in a study by Metcalfe et al. Seven survey respondents acquired permanent manure application easements on others' land or developed long-term contracts with other landowners for manure application. Though two respondents had contractual arrangements for a price greater than $0, the small sample size limits the strength of any statistical conclusions revealing crop producers' demand for livestock manure.

Nunez and McCann conducted a study about Missouri and Iowa crop producers to determine what factors influenced an individual's willingness to use manure. The study identifies the factors significantly influencing acceptance of manure to be profitability, age, location, uncertainty, and awareness. As the profitability increases and uncertainty about the manure's effect on the land relative to commercial fertilizer decreases, producers' willingness to use manure increases. The study also indicates that farm systems determine producers' likelihood of acceptance, suggesting some production systems are better suited to utilize manure applications. Nonetheless, this study, as well as others previously mentioned, is deficient in one area. It fails to place a monetary value on livestock producers' manure. As indicated, this information is imperative for the livestock producer to understand her fiscal situation.

Determining monetary value for manure by estimating crop producers' willingness-to-pay requires the use of non-market valuation methods. Previous studies have employed traditional valuation procedures, but revealed little about the potential detriment to producers facing governmental regulation. As a result, this study determines manure value by means of non-market valuation estimators in a random utility framework, using survey responses from Oklahoma crop producers to determine the likelihood that a crop producer would pay a specific price for manure. Subsequently, a discussion follows about the emergence of non-market valuation estimators and their general applicability to economic problems. More specifically, contingent valuation is introduced for its flexibility in assessing economic value in hypothetical markets.

Non-Market Valuation Tools

A fundamental concept of economics is the determination of value. By discovering value for individuals, utility functions can provide insight about the specific attributes that determine value and aid in constructing inverse compensated demand curves (Lusk and Hudson). As a result, the fundamentals of valuation are nearly as old as economics. Throughout history, two practices have emerged to determine value: market-based approaches (also known as revealed preferences) and non-market-based valuation approaches (commonly referred to as stated preferences) (Elliott, Reed, and Franklin). These two methods are widely used in the determination of value. However, until the last half-century, only market-based valuation existed.

Prior to the emergence of non-market valuation procedures, researchers and economists had few options to estimate the effects of policy and economic stimuli. Traditionally, market based approaches have been excellent tools for estimating the values of goods and services in which some type of market transaction could be observed. The three most commonly applied market-based approaches are the cost approach, the income approach, and the comparison approach (Elliott, Reed, and Franklin). Previous literature in the field of manure management has yielded studies in which the cost approach was employed to determine the effects of waste management policies. Feinerman, Bosch, and Pease determined the cost components to apply, handle, and transport livestock manure to cropland. Then, they estimated the potential value of manure based on its nutrient content by determining a social welfare benefit from the replacement of commercial fertilizer with animal manure and the costs of application. This study suggests a positive value should be observed for manure. However, Glewen and Koelsch, observing a limited number of real market transactions, reveal that 54% of manure was transacted at the price of $0. This illustrates a potential weakness in the cost approach, as estimates are not representative of real market transactions.

Another study by Ribaudo, Cattaneo, and Agapoff estimates the costs of meeting nutrient standards imposed by the Clean Water Act's legislation. This study employs the cost approach and considers cost share components available to producers through the Environmental Quality Incentives Program. Noting the potential of cost share programs to influence producers' decisions, the researchers cite that demand for manure is driven by factors besides nutrient content. The study reveals aggregate cost estimations based on speculation about the percentage of producers willing to accept manure. Though the study estimates cost, it fails to analyze the problem on a microeconomic level and provide any details about the individual behavior of a crop producer. Many market-based approaches continue to provide insightful information, but deficiencies in traditional approaches' ability to determine the WTP for non-marketed goods and the lack of monetary values are subordinate to the capabilities of contingent valuation.

Similar deficiencies in research resulted in the dawning of non-market valuation in the 1960s to assist in placing an economic value on goods and services in which little to no observable market existed (Portney). Many non-market valuation procedures have since emerged to value items, such as, environmental attributes, national parks, non-market tested products, endangered species, sparsely or uncommonly traded goods, etc. Throughout this period of advancement, contingent valuation has become the most widely used and accepted practice in estimating willingness-to-pay. The main reasons for implementation are its ability to estimate passive use values and provide flexible data collection procedures (Carson, Flores, and Meade)[7].

[7] Existence or passive use values are described as the utility an individual gains from the knowledge that endangered animals, threatened environments, or other unique objects exist.

A contingent valuation study most commonly administers surveys or questionnaires to individuals ascertaining the monetary value a respondent places on a hypothetical product or project. Further, as the name suggests, values determined using this method are conditional upon a specific situation or market that is described within the elicitation process (Portney). For example, consider a telephone interview where an individual describes an unfamiliar product to you. After describing the product, the survey administrator then provides a brief description of a hypothetical market and attributes specific to the product being sold. Given this information and calling upon your own consumer knowledge, you are then asked to provide your monetary value of the product. In other words, how much would you pay to own this product? This procedural aspect of questioning respondents about products that have not been previously assigned values in a market is the component of contingent valuation that has been widely criticized. Many opponents have demonstrated widely varying estimates dependent on the context in which the theoretical market is established. In defense of the contingent valuation method, Alan Randall made the following statement in 1986.

> "… the goods offered in contingent markets are not always familiar, and individuals may not associate these particular goods with trading possibilities. Nevertheless, unfamiliar goods are often introduced in "real" markets and, especially, in market experiments. So the distinction between 'real' and contingent markets is, if anything, a matter of degree."

Thus, the controversy surrounding contingent valuation is as much a philosophical argument as a methodological one. Nonetheless, controversy and criticism continues to drive methodological improvements implementing corrective procedures and producing more reliable valuations.

Originally, contingent valuation had its roots in public sector economics determining the values of environmental and natural resources. Portney notes that (Robert) Davis first implemented the idea of contingent valuation by surveying hunters and wilderness lovers about their value of a specific recreational area. However, contingent valuation's monumental emergence began with John Krutilla's "Conservation Reconsidered," where he suggested that this procedure could estimate the existence value to individuals (Portney). The ability of contingent valuation to measure existence value has accelerated its use, yet has been the central component of controversy and criticism surrounding its application in economics. Advocates of contingent valuation argue that without the inclusion of passive use values, studies reveal little to no measurable economic value for public goods. Conversely, proponents argue that existence values are the source of gross overestimations of a good's economic value. This characteristic of overestimating value is referred to as hypothetical bias and has been contingent valuation's largest source of controversy.

Hypothetical bias is a phenomenon that arises when subjects are questioned about their willingness-to-pay for a hypothetical good. Respondents tend to overestimate their true value of a good. Champ and Bishop describe the source of bias as respondents who have positive feelings toward a project or good but do not actually purchase in a real market. As a result, a second area of debate involves the theoretical qualifications that a contingent valuation study should satisfy. Researchers now suggest that to ensure unbiased value calculations, estimates should follow basic demand theory in terms of price sensitivity, comparing estimates using alternative procedures, and satisfying scope tests, where consumers recognize and pay a difference for greater quality (Carson).

Prior to the Exxon Valdez oil spill, researchers and economic analysts were using contingent valuation with relatively little standardization among practices. However, when the Oil Pollution Act of 1990 (in response to the spill) prompted action to prevent future oil spills and damage assessment procedures, contingent valuation was placed in the center of a heated debate. To this point, few environmental court proceedings involving contingent valuation possessed the visibility and widespread economic impacts felt by fisherman, resort owners, and the general public hurt by the spill (Portney). At the time, casual practices of contingent valuation could have generated existence value reparations for Exxon Valdez far exceeding any realistic monetary figure. As a result, the National Oceanic and Atmospheric Administration (NOAA) appointed a panel of non-market valuation authorities to determine whether existence values derived from contingent valuation were "reliable" measures of damage assessment. The ensuing report published by the panel in 1993 generated numerous recommendations and guidelines to decrease the wide disparity among contingent valuation studies. The panel described past methods as "casual" and identified a serious need for reform.

The greatest problem with contingent valuation is the tendency to overestimate the WTP of surveyed individuals in a theoretical market. As previously mentioned, hypothetical bias is a product of numerous problems that severely limit the reliability of any test. As a result, the panel identified several problems that required attention: (1) contingent valuation methods may generate results contrary to rational producer choices, (2) individuals fail to realize the potential income reduction, making a decision to donate based only on the consideration of one project and not if all public programs were funded similarly, (3) a majority of previous studies have failed to remind respondents of their own personal budget constraints, (4) thoroughly explaining a policy or program for a respondent to make an informed decision is very difficult, (5) market boundaries can significantly influence the estimates, and (6) respondents may indicate a greater WTP because they feel as if they are contributing to a good cause rather than in support of a specific program (also known as the "Warm Glow Effect").

Survey Design

NOAA's report has since served as a benchmark for contingent valuation studies. As a result, an abundance of literature exists that greatly expands the evidence behind contingent valuation criticisms and corrective elicitation procedures. Carson et al. indicate that contingent valuation mechanisms that produce questionable results, often fail because the administrator fails to clearly explain the good, the provision mechanism, or the payment vehicle. In response to these concerns, List and Gallet conduct a meta-analysis of previous studies to better understand the influence that survey design characteristics have on hypothetical bias. Evidence indicates that mechanisms and numerous tools used for eliciting value are responsible for disparity observed between stated and actual preferences. Therefore, it is imperative that survey designers employ a standard procedure to elicit unbiased estimates.

In reaction, numerous studies have outlined the necessary components to ensure an unbiased survey. Collectively, research suggests (1) an introductory section that provides background information for the respondent that identifies a context in which the market exists, (2) a detailed description of the product being considered, (3) details of the transaction, including payment mechanism, (4) potential consequences of the program/project, (5) a reminder about the individual's budget constraint, (6) information gathering attitudinal and demographic characteristics, (7) and one or more follow-up questions to ensure that the respondent understood her decision (Carson; Portney; Arrow, et al.).

Elicitation Mechanisms

An article by Lusk and Hudson focused on determining WTP decisions for agribusinesses and its usefulness in determining demand components for non-marketed goods. Lusk and Hudson state that choosing the mechanism that aligns the appropriate incentives is an important consideration. Carson et al. characterize the dilemma a researcher faces as one of two evils. They state that the elicitation format a researcher employs depends on whether one prefers a format that is unbiased with a large confidence interval or a format that may be potentially biased, but with a much tighter confidence interval. As a result, a number of mechanisms exist for eliciting survey participants' value. One decision affecting the mechanism an individual employs is whether the surveyor seeks discrete or continuous values. Ready, Buzby and Hu cite that continuous estimation procedures commonly use two approaches: (1) open-ended questions, where respondents state their maximum willingness-to-pay for a product, or (2) the payment card approach[8], where the individual chooses a WTP from a list of printed values. Alternatively, the study cites that the most common discrete estimation procedure is in the form of dichotomous choice questions. Lusk and Hudson further discuss dichotomous choice questions and their appeal in contingent valuation studies.

[8] The payment card approach provides respondents with a card containing a range of prices in which they are then asked to determine a willingness-to-pay point estimate from the list of values defined by the surveyor.

Under this mechanism, the survey provides a respondent with a discrete value (i.e. $10, $7, $14.06, $3.43) and then asks whether she would be willing to pay the stated price by responding "Yes" or "No."

Briefly highlighting the differences between continuous and discrete methods, Ready, Buzby, and Hu state that continuous procedures generally provide lower estimated values and provide more information about an individual's WTP. However, discrete surveys have become the more widely used practice. The most popular discrete method used is the dichotomous choice question, because it places consumers in a situation similar to a grocery purchasing decision. Though valuation differences have been found to exist between continuous and discrete valuation procedures, Ready, Buzby, and Hu indicate a study conducted on private goods yielded no significant difference between discrete and continuous valuation estimates. Of the difference between continuous and discrete procedures, dichotomous choice methods (discrete procedure) yield estimates that are 3.6 to 4.4 times as large as the payment card valuation (continuous procedure).

The NOAA panel also endorses the use of a "referendum" format. This format arranged in the form of a dichotomous choice question asks respondents if they are willing to pay the average amount implied by the referendum under question. The panel cites several reasons for choosing this elicitation method over other methods. The panel believes that presenting the choice problem in a broad context allows the respondent to arrive at a more realistic and conservative estimate. Moreover, the panel notes that open-ended questions lack realism in the context that consumers rarely determine their own value for a good. They believe the open-ended method is more prone to increase the probability of hypothetical bias and data that are erratic and biased. Despite dichotomous choice's shortcomings, NOAA feels it is most appropriate for assessing economic value.

Discrete estimators are the most practical and simplistic elicitation procedure. In Lusk and Hudson's study detailing agribusiness decisions and determining WTP, they outline a number of discrete elicitation tools and describe the situations that best use the procedure's concepts.

One discrete elicitation tool not previously mentioned is the double-bounded dichotomous choice question, similar to dichotomous choice but involving an additional step. Double-bounded questions provide the respondent with a second question that is contingent on the individual's first response. In this case, one survey provides two observations of WTP rather than one (Lusk and Hudson). For example, if an individual answers "No" (as in not willing to pay the initial price), a second question is then administered where the individual is asked if they would pay a lower stated price. In the same respect, if an individual answers "Yes," then the second question provides a higher price. Though commonly used to create statistical efficiency, double-bounded questions are subject to several problems (Lusk and Hudson). A study by Cameron and Quiggin has shown that the observed WTP values of double-bounded questions are not perfectly correlated, bringing into question which observation should be given more statistical importance. Additionally, numerous studies have identified the problem of starting point bias associated with this procedure. Here, an individual's response to the second question is said to depend on the starting value of the first question (Lusk and Hudson).

Choice-based conjoint analysis is a second mechanism that can be used to derive WTP (Lusk and Hudson). In this framework, the methods ask the individual to determine which product she would prefer, provided a specific set of product attributes or circumstances such as price, quality, etc. One procedural advantage is that it mimics the purchase decisions that consumers face (Lusk and Hudson). Therefore, one would be inclined to think that respondents are more likely to portray their true WTP. Though several advantages accompany the mechanism, its design features can be difficult to administer and considering product attributes can overwhelm survey respondents into making a random selection or abandoning the survey altogether (Lusk and Hudson).

Another method gaining popularity is the use of experimental auctions. This method designs an auction scenario where a consumer's bid for a product reflects her WTP. A number of auction alternatives exist to elicit value from market participants, such as English or random *n*th auctions. Although each procedure creates a different level of buyer interaction, Lusk and Hudson state that theoretically the method should yield the same value if bids are independently distributed. However, procedural expenses and dependently distributed bids from the lack of participant interest limit auction benefits (Lusk and Hudson). A number of elicitation mechanisms exist, and all will elicit product value. The difficulty lies in selecting the method that will align most appropriately with a study's objectives.

Hypothetical Bias

Numerous procedural remedies seek to decrease the hypothetical bias of contingent valuation and increase its statistical reliability. Calibration and cheap talk are two of the most commonly employed practices to reduce hypothetical bias and provide a conservative estimate. Cheap talk is an *ex-ante* reminder to the survey respondent of her tendency to overstate values (Lusk). Alternatively, calibration is a form of *ex-post* reminder, where the respondent is asked to rate the certainty that her stated preference matches her WTP in a true market setting (Champ and Bishop).

Surveys designed with a cheap talk script include an explanatory statement that precedes the contingent valuation question informing the respondent about problems with hypothetical bias. The purpose is to directly influence individuals to provide a response that more closely resembles actual WTP. Cummings and Taylor, one of the first to utilize the idea of cheap talk, reveal that stated preferences are significantly lower in surveys where cheap talk is used. This leads Cummings and Taylor to conclude that cheap talk is successful in eliminating hypothetical bias to the point that hypothetical responses are not statistically different from revealed values. Similarly, Lusk implements a cheap talk design in valuing a private good. Finding that cheap talk has a significant affect on reducing hypothetical bias, Lusk explores the correlation between product knowledge and WTP. Lusk finds that individuals familiar with the product being valued are not significantly affected by the cheap talk. However, respondents less familiar with the topic are significantly influenced by cheap talk. He concludes that cheap talk is effective at reducing hypothetical bias in respondents unfamiliar with the product being valued. Conversely, Murphy, Stevens, and Weatherhead find that cheap talk does not effectively eliminate all hypothetical bias as had been earlier suggested. They conclude that because many respondents have well-formed preferences, cheap talk does not influence their level of donation. Whether cheap talk can eliminate hypothetical bias or simply reduce it, studies have proven it yields more accurate valuations.

Another strategy to reduce hypothetical bias is calibration. Calibration attempts to measure how certain an individual is that her stated behavior would be the same in a real market transaction. Champ and Bishop find that coding "uncertain" positive responses[9] to negative responses[10] reduces any hypothetical bias to the level that estimation results are indistinguishable from actual observations.

In determining an individual's certainty, the most common procedure is to implement a ten point Likert scale. Under this scenario, a respondent who indicates that she would pay/donate the stated survey amount is asked to circle a number from one to ten (1 being very uncertain, and 10 being very certain) to indicate her level of certainty that she would indeed make the purchase and pay the stated amount if given the opportunity (Champ and Bishop). Though calibration can effectively reduce hypothetical bias, determining the threshold value to recode positive responses to negative responses is difficult. Champ and Bishop note that a hard and fast rule does not exist. For example, Champ et al. find that individuals with a certainty level of ten effectively eliminated hypothetical bias for a study conducted about public goods. Conversely, Champ and Bishop identify eight as the appropriate threshold value in a wind power study. Other studies identify that certainty as low as six or seven indicates true behavior. List and Gallet indicate that private goods have lower threshold factors in comparison to public goods. As a result, understanding the advantages of using calibration to reduce hypothetical bias is imperative for the researcher, but one must also be aware of the difficulties associated with identifying the proper threshold value. In the final section of

[9] A positive response is defined as a respondent who answers "Yes" to a contingent valuation question. An "uncertain" positive respondent is one who answers "Yes," but has a certainty level below the threshold value.

[10] A negative response is defined as a "No" answer to the binary question.

this chapter, the researcher attempts to identify demand factors for livestock manure and their implications on this study.

Demand for Livestock Manure

Determining the demand for a good is a complex task that requires consideration of a number of factors. In the case of livestock manure, one must realize that crop producers are relatively unfamiliar with its use as a fertilizer. When a product, such as manure, is not a widely used and understood, many factors in addition to theoretical demand shifters must be considered. Simplistically, demand is the quantity of a product purchased at different prices, *ceteris paribus* (Cramer, Jensen, and Southgate). Changes in the quantity demanded for a product are dependent on price, but many factors also stimulate a change in demand. These factors include changes in income, changes in population, changes in relative prices of substitutes and complements, and changes in tastes and preferences. This known, the researcher seeks to identify what creates both the changes in manure demand and what influences price movement for the product.

Feinerman, Bosch, and Pease conducted a study about the demand for manure under different governmental regulatory practices. This study assumed that the demand for manure was elastic depending on its own price, the prices of other competing goods (commercial fertilizer), productivity of the soil, nutrient composition of the soil, nutrients required by the crop, and regulatory practices affecting application rates. The agricultural industry is witnessing a burgeoning increase in the cost of chemical fertilizer due to rising natural gas prices. As prices continue to increase, the demand for manure as a fertilizer substitute is growing and becoming more economical (Burns). However, as producers seek out sources for manure, many manure attributes discourage and other attributes encourage the decision to apply manure to cropland.

The primary reason for using manure as a substitute is the reduction in commercial fertilizer costs. Burns states that one ton of poultry litter contains $32 to $35 worth of nitrogen, phosphorus, and potassium. Previous studies by Glewen and Koelsch have suggested that crop producers may be able to obtain these nutrients for little to no cost. Though crop producers may have to pay a small price, the idea is that market research suggests crop producers are not paying the full nutrient value of manure.

Ribaudo, Cattaneo, and Agapoff note that demand is more than a function of the nutrient value. One of the benefits manure offers over commercial fertilizer is increased organic matter content that improves both physical and biological soil composition. Subsequently, water infiltration increases, leading to improved crop yields (Wortmann). He notes that manure is more valuable when a nutrient build up is desired in the soil.

One primary concern about using manure as an alternative is the lack of uniformity in the rate of application and manure composition (Wortmann). Glewen and Koelsch conducted a study on services provided by feedlots to increase the value of manure. With nutrient variation a main concern to crop producers, the study found that most feedlots exporting manure from the facility offered at least one service by conducting manure sampling, measurement of application rate, or adjustment in application rate for individual crop and field conditions.

Ribaudo, Cattaneo, and Agapoff note that high transportation and handling costs relative to commercial fertilizer may discourage demand for manure. Mentioned earlier as a positive attribute, organic matter in manure contributes to its bulkiness as a good and requires greater volume to transport the same amount of nutrients relative to commercial fertilizer. This leads to two other drawbacks. Additional trips equate to increased soil compaction from spreading equipment and higher transportation costs. Wortmann also cites that weed seed and foreign debris such as rock or concrete from feeding facilities can reduce the overall value of manure.

Another characteristic about manure that can be considered both negative and positive is the nutrient release. Unlike commercial fertilizer, manure is slower to release its nutrients. A publication by Mitchell and Donald notes that about 70% of the total nitrogen in chicken litter will be available the first year. This is because manure must endure a decomposition phase to mineralize the nitrogen into a usable form by plants. Likewise, phosphorus and potassium are considered about 75% as effective as commercial fertilizer in the first year. For producers who have not had repeated applications of manure, this effectively reduces the value of the manure from approximately $35 a ton to around $25 a ton. However, producers applying manure for several years, realize the residual value of unused manure nutrients from the previous season. The slow release of nutrients also ensures a steady supply of nutrients throughout the growing season. Granted, some crops such as corn require a very timely application of nutrients to ensure maximum yield.

The method of application and the form of the manure also play a large role in creating manure value. Manure is predominately applied topically to the soil, or it is incorporated (injected sub-surface). There are several benefits to injecting manure. The first is the reduction in the loss of nitrogen. Mitchell and Donald note that applying broiler litter to the surface will result in a 5% to 20% loss of total nitrogen. When manure is spread in the form of a liquid or semi-liquid, as much as 25% of the total nitrogen can be lost to the atmosphere within seven days after spreading. Nonetheless, incorporation is not practical for situations including pasture, hay fields, or planted crops.

Another incentive to incorporate manure is to avoid complaints from neighbors and pest problems. As the rural resident composition has changed, fewer residents are involved in agriculture and may perceive common application practices to be offensive and threatening to environmental amenities. Glewen and Koelsch found that 60% of feedlots exporting manure have encountered some form of environmental or nuisance related concern. The three most common were odors (28%), road traffic (26%), and road maintenance (24%). For many crop producers, the chance of having an encounter with a neighbor about odor or pests may not be worth the savings in fertilizer costs. To reduce this problem and others, some livestock facilities are composting manure. Composting helps to reduce total moisture, which means less weight, reduces odor, and decreases weed seed germination. However, Mitchell and Donald note that nitrogen loss is greater in composted manure and the nitrogen is less available to the crop because of the conversion from ammonia (usable form to plants) to organic (unusable in the short run).

Among all these factors, Feinerman, Bosch, and Pease also cite that governmental regulations may influence a crop producer's decision to seek manure. As application restrictions become stricter for animal feeding operations, precise application rates must be recorded. In some instances, crop producers must grant an easement to the livestock producer for liability stipulations outlined by the EPA. Restrictions requiring manure to be applied based upon soil composition, slope of the soil, expected cropping activity, and soil test levels all contribute to a more complicated process that decreases the value of manure (USDA, USEPA).

Perhaps even more indicative of the manure demand components are studies conducted by Nunez and McCann and Wossink and Boonsaeng. Wossink and Boonsaeng surveyed 66 North Carolina swine producers to access their knowledge and perceptions about waste management technologies. Interesting in regard to our study is a question asking respondent's opinions about what aspects of hog production need to be addressed to increase public acceptance of hog production facilities. The study found the following factors were all considered significant in the minds of swine producers: ammonia emissions from farms, excess land application of phosphorus and nitrogen, ground and surface water contamination, transfer of pathogens in soil and manure, and farm odors. Ground and surface water contamination were considered the two most important aspects that needed to be addressed.

Nunez and McCann's study was more specific in identifying factors that influenced a crop producer's willingness-to-use livestock manure as fertilizer. Their study identified perceived profitability, crop producer uncertainty, awareness of other farmers using manure, age, and location as significant factors influencing a producer's willingness-to-use. Across a sample of 775 respondents, producers were more likely to accept manure if they believed they could increase profits. As well, decreasing uncertainty and increasing awareness of other surrounding producers using manure also increased willingness-to-accept manure. Older producers were also less likely to use manure as a fertilizer source. Finally, Nunez and McCann found that geographical location influenced willingness to accept manure. The sample of both Missouri and Iowa producers suggested that Iowa producers were more willing to accept application and suggests that cropping systems in Iowa are more conducive to accepting manure.

In review, numerous factors have been identified in studies and literature that influence the demand for livestock and poultry manure as a substitute or supplemental fertilizer source. To summarize these factors, a compiled list of factors influencing the demand for manure follows.

1. Price of Manure
2. Changes in Producer Income
3. Changes in Price of Commercial Fertilizer
4. Soil Composition
5. Residual Nutrient Composition of Soil
6. Crop Nutrient Requirements
7. Manure Composition: Nutrient and Organic Material
8. Uniformity of Manure across Applications
9. Transportation Costs
10. Soil Compaction
11. Weed Seed and Foreign Material
12. Rate of Nutrient Release
13. Method of Application: Incorporation or Topical
14. Odor and Pests: Increase Probability of Neighbor Encounters
15. Manure Form: Liquid, Solid, or Slurry
16. Federal Regulatory Requirements
17. Profitability
18. Contamination of Water Supplies
19. Age of Producer
20. Crop Producer Uncertainty about Manure Capabilities
21. Knowledge of Surrounding Producers' Experience
22. Transfer of Pathogens to Soil
23. Location of Crop Producer

This extensive list, although not exhaustive, indicates it is unrealistic to attempt to measure all factors influencing crop producers' willingness-to-pay for manure. As a result, in the next chapter, variables deemed most important by the researcher are measured to estimate crop producers' WTP. One should note that when all explanatory variables for a decision cannot be measured, one must focus on the marginal impact of explanatory variables for analysis.

In the field of contingent valuation, fewer studies have utilized the method's flexibility to represent decisions faced by agricultural producers concerning private goods such as this study does. In viewing livestock manure as a recyclable, private good, this study considers a unique situation and extends into a far less researched area of contingent valuation. The next chapter will demonstrate the survey methodology employed and summarize respondent data to provide insight into this study's design and objectives.

DATA AND METHODOLOGY

Governmental regulations enacted by the Environmental Protection Agency in 2003 are forcing many livestock producers to distribute the same amount of manure over a significantly larger land area. These regulations create the potential for increased costs to be levied on livestock producers. Two major components determining the cost of spreading manure is the distance it must be hauled and the number of localized crop producers willing to pay for manure. To better identify the potential economic impacts of these regulations, this study determines components affecting crop producers' willingness-to-pay (WTP) for manure by administering a contingent valuation survey. (See Appendix I for the complete survey instrument.)

This study's objective is to identify the factors affecting a crop producers' decision to purchase manure and the probability that a producer will pay a certain price. Therefore, the inverse demand for manure is modeled as:

$$WTP=f(X_i) \tag{1}$$

where willingness-to-pay for manure, *WTP*, is a function of manure attributes and producer preferences, represented as X_i.

Numerous valuation procedures have been used to determine the economic value of a good's attributes by observing transactions. Some of the most popular methods estimating value include regression analysis, benefit-cost analysis, and appraisal techniques. Remember from the literature that these methods rely on data detailing observable market transactions. In the field of animal waste management, previous studies have attempted to place value on hypothetical transactions based on broad assumptions. Unfortunately, these studies do not reveal manure attributes that create value for crop producers. To obtain these data, a different methodology is required.

Several reasons inhibit the ability to gather data and conduct an informative and conclusive study. The first is that few market transactions occur between crop and livestock producers for manure, and furthermore, these exchanges poorly document the conditions surrounding an exchange. Previous studies conducted by Feinerman, Bosch, and Pease and Glewen and Koelsch have done little to define demand components for crop producers. In reviewing Glewen and Koelsch, results are limited to summary statistics that provide little indication of crop producers' preference. Feinerman, Bosch, and Pease determined value by assigning application, handling, and transportation costs to the manure nutrients. Without consideration for other demand factors such as type of manure, moisture content, fertilizer needs, or market structure, the two studies reveal few characteristics about the real market value.

This study seeks to obtain data that allows one to value manure based on manure attributes and the demographics of the manure buyer. To satisfy these objectives, data must be collected detailing the circumstances surrounding a transaction. Lacking a sound and observable market for data collection suggests designing a hypothetical market where crop producers indicate preference for a product. Eliciting data by means of hypothetical questioning allows the surveyor to measure and control the manure attributes. Recall the discussion in the previous chapter discussing non-market estimators. Contingent valuation was defined as a method to ascertain the monetary value an individual places upon a service or product through administration of a survey or questionnaire. The survey respondent is presented with a hypothetical good described by its attributes and is asked to value the good. This allows one to directly estimate value as a function of its attributes. In the case of this study, a respondent is asked to value manure based on the attributes defined in the contingent valuation survey.

Techniques for Eliciting Manure Value

Survey Administration

The contingent valuation survey was administered by Bailey Norwood, an assistant professor of the agricultural economics department at Oklahoma State University. The survey was mailed to 512 Oklahoma crop producers in October of 2003. The sample population, attained from a university database, included the names of individuals actively involved in production agriculture. These individuals had been previously identified by state and county extension agents as producers willing to participate in university research projects. For these reasons, a high response rate was anticipated. The survey generated 289 useful responses (56.4% response rate).

A pretest survey was administered to self-proclaimed crop producers attending Oklahoma State University. This helped determine the approximate time required to complete the survey, identify any confusing concepts, and verify the receptiveness of surveyed crop producers.

The survey tool included 11 questions measuring demographic variables, respondent preferences, and crop producers' WTP for manure given a specific set of product attributes. The front page of the two-sheet booklet informed the individual of federal regulations that will affect manure application practices. Further, the survey informed the recipient of Oklahoma State University's efforts to minimize the regulatory impact to Oklahoma farms.

To obtain the most knowledgeable responses, the survey asked that the respondent be the individual "most responsible for farm management on (the) operation." This suggestion helped ensure survey respondents were most familiar with the concepts of fertilization and the challenging effects of regulations restricting the application of animal manure. To further encourage participants' response, the survey included a pre-paid postage envelope and attempted to stimulate the attitude of cultural preservation by characterizing a returned response as a philanthropic service to the "Oklahoma farm community."

Crop Producer Demographics

Oklahoma, known for its oil wells, wheat, and cattle, is recognized across the nation as an agricultural state. According to the Oklahoma Department of Agriculture's website, Oklahoma is home to 85,000 farms and ranches that on average cover about 400 acres. Beef production in Oklahoma ranks fourth in the nation and contributes approximately $2 billion to the state's cash receipts in agriculture. As a major feedstock for the Oklahoma cattle industry, winter wheat production in Oklahoma ranks second nationally and is the state's top cash crop, exceeding $500 million in agricultural sales. The Oklahoma swine industry has also risen to national prominence since state legislation in 1991 promoted the development of larger facilities.

One appealing aspect of conducting such a survey in the State of Oklahoma is the climatic differences between regions in the state and the diversity of both livestock production facilities and crop production practices. To further explain, imagine Interstates 40 (east to west) and 35 (north to south) as regional boundaries dividing the state into four quadrants (Figure 4.). Referring to statistics available from the National Agricultural Statistics Service, we can summarize the types of agricultural production observed in each region.

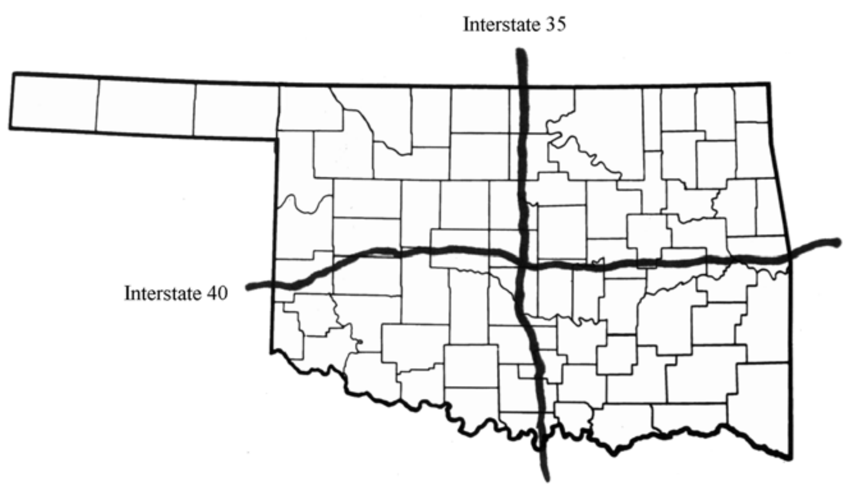

Figure 4. Interstate Regional Boundaries of Oklahoma
Source: Oklahoma State University, Division of Agricultural Sciences and Natural Resources

The northwest quadrant, including the panhandle, is predominately characterized by feeder and stocker cattle, large swine operations, and crop production, some of which is under center pivot irrigation. Texas County, in the panhandle, is one of the most densely populated swine counties in the nation, and houses the largest swine facility and cattle feedlot in the state. The northwest also produces the most significant portion of Oklahoma's winter wheat. This region is the only area that produces a significant amount of corn and silage corn, mainly due to the irrigation water available from the Ogallala aquifer. Many producers in this area already practice effluent application on their crops. This situation provides an audience that we expect will be well informed about waste management issues, nutrient runoff, and the potentially damaging consequences from underground water contamination.

The southwest's arid climate is appropriate for cotton, peanuts, and winter wheat production. The area includes a few beef cows, but is better suited for feeder cattle. Though similar to the northwest, farms in the southwest are generally smaller in scale. This region offers an audience that may be less familiar with waste management issues and the application of livestock manure to cropland.

The northeastern quadrant possesses a wetter climate, and rougher terrain more conducive to beef cow-calf and poultry production. Area crops include a small amount of corn and soybean production, but the land predominately lends itself to hay production. This region has also been the center of many environmental questions due to the high concentration of poultry facilities, limited nutrient uptake by hay and pastures, shallow top soil, and the vast network of rivers, lakes, and streams that dissect the area and promote nutrient movement. This quadrant of producers is expected to be adept to the environmental issues surrounding waste applications.

The southeast is similar to the northeast in the respect that agricultural production in this area is largely poultry and beef cow-calf production. Fewer swine facilities are found in the southeast in comparison to the northwest. With respect to crops, the southeast is the wettest region in the state and is used predominately for hay and timber (forestry) production. Figure 5 graphically identifies the number of survey respondents in each respective region.

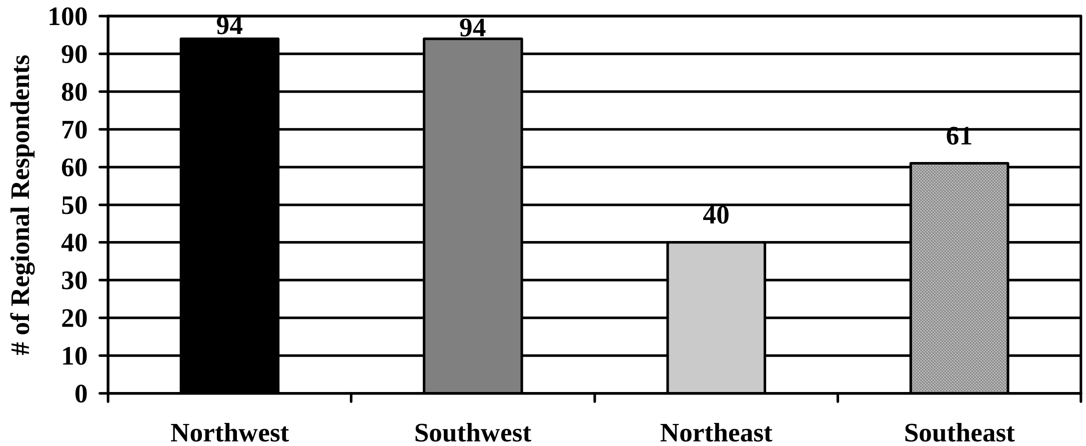

Figure 5. Regional Distribution of Survey Respondents

The state provides a unique case study with an audience both familiar and unfamiliar to the issues of waste management. Oklahoma includes a diverse set of crops, production facilities, climates, and terrain that vary significantly from the northwest to the southeast. This survey anticipates a better understanding of crop producers' knowledge in different regions and their preferences for manure as a fertilizer alternative.

With a regional understanding of the state's agricultural production practices, we now address the demographical section of the survey. Creative Research Systems, a survey design consultant, suggests that the first questions in a survey should be simple to answer, encouraging participation throughout the survey. Therefore, demographical questions followed the introductory section to acclimate respondents to the waste management topic. Three questions appeared on the back of the first page, asking producers to indicate the crops managed, the number of acres under management, and any livestock managed.

The first survey question prompted producers to mark any of the crops they managed. This question identifies the distribution of crop management and helps ensure a representative sample of the entire state. The most commonly managed crop is pasture at more than 70% of the respondents. In evaluating this statistic, note that the survey's interpretation of "crop producer" includes all individuals who manage both forages and grain crops. Thus, improved and native grass pasture managers are considered "crop producers" in the context of this study. In identifying this group of producers, we acknowledge that the difference between improved and native grass pasture was not established. Therefore, we must assume that this category includes both types.

Several other categories registered high percentages of management, including winter wheat and hay production. Table 1 lists the crops available for selection in the survey and the percentage of responding producers managing the crop.

Table 1. Percent of Respondents Managing Crop Types

Crop	Percent of Total
Winter wheat for grain	48.8%
Winter wheat for grazing	61.6%
Winter wheat for grain and grazing	56.1%
Corn for grain	8.3%
Corn for silage	2.1%
Grain sorghum	16.3%
Soybeans	15.9%
Alfalfa hay	30.8%
Other hay	59.2%
Pasture	72.0%
Cotton	4.1%
Oats	6.2%
Barley	1.4%
Rye	10.4%
Peanuts	3.1%
Other	6.6%

Note: Producers were allowed to mark more than one category.

Measuring the number of acres managed is another indicator ensuring a representative sample. Determining the land available for spreading is important to assess overall market potential and regional analysis. Thus, the next question asks crop producers to indicate the number of crop and pasture acres they currently manage. In this survey, a bimodal distribution was observed with the two largest percentages in the categories of 0 to 499 acres and 1,000 to 2,999 acres. Comparatively, National Agricultural Statistical Service (NASS) data of farm numbers from the 2002 Census of Agriculture indicates slightly different estimates. Referring to Figure 6, observe the much larger percentage of farms distributed in the smaller acreage categories than this survey depicts in Figure 7. NASS statistics indicate that 82% of Oklahoma's farms are less than 500 acres. Conversely, this category of survey respondents makes up only 28.2% of surveyed farms. Likewise, NASS finds that 9.2% of Oklahoma farms fall in the 500 to 999 acre category where this sample indicates 19.2%. The average size of NASS farms is 403.5 acres. Surveyed respondents' average farm size is 2,174.0 acres. Weighted averages are determined using the midpoint for each category and the upper bound categories are assigned a value of 3,500 acres and 12,000 acres, respectively.

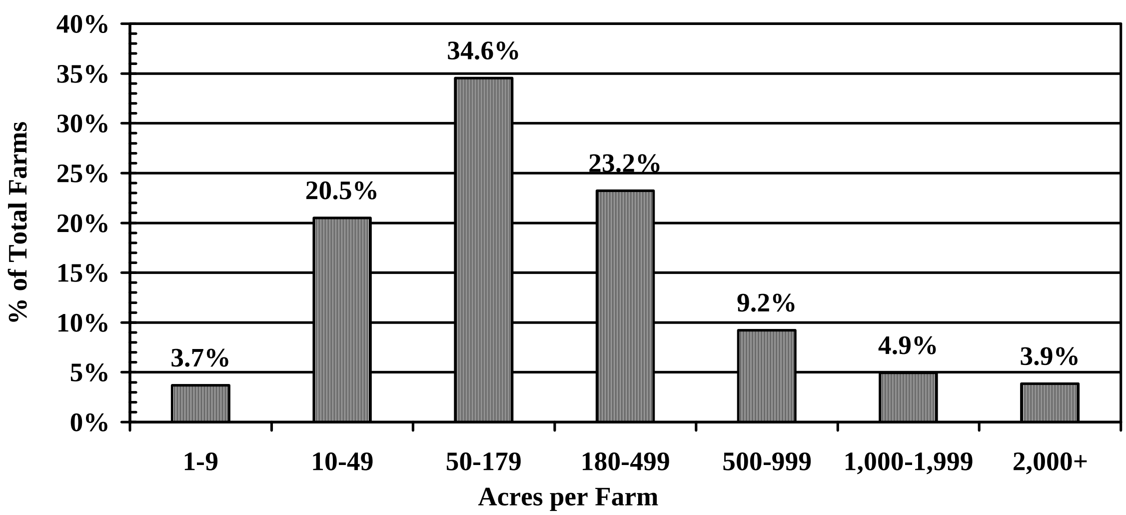

Figure 6. Acre Size of Oklahoma NASS Farms
Source: NASS Quick Stats

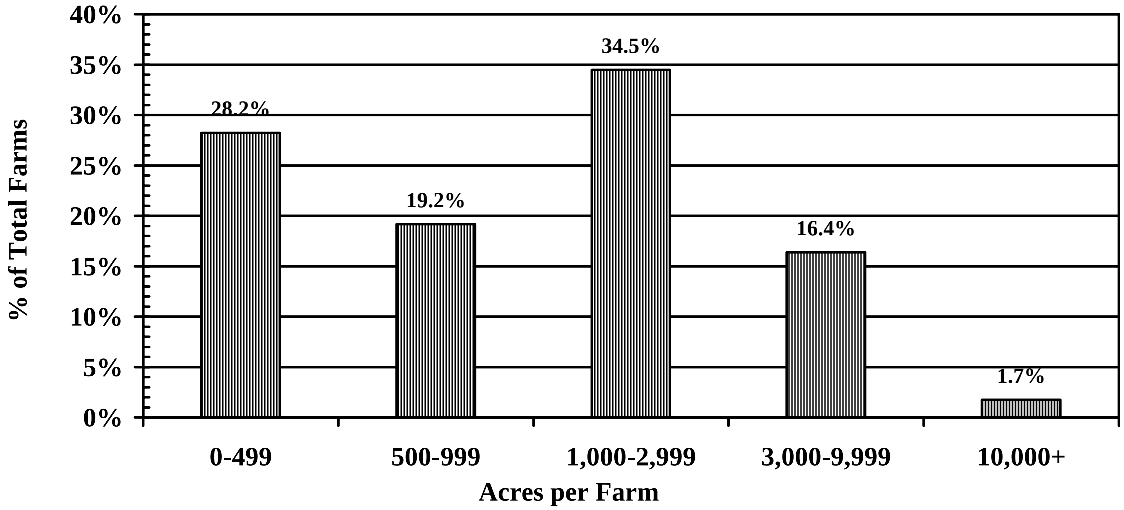

Figure 7. Acre Size of Surveyed Oklahoma Farms

A couple of factors can explain this anomaly between the data. The United States Department of Agriculture identifies a farm as an operation with at least \$1,000 of agricultural sales in a fiscal year. Although these small farms comprise a significant portion of American agriculture, recall the scope of our survey is to determine a market outlet for large quantities of livestock manure. Consider that it takes less than 30 acres of wheat with a yield of 30 bushels per acre and a price of \$3 per bushel to exceed \$2,500 in agricultural sales. Nearly 36% of Oklahoma farms fall below \$2,500 in sales (2002 Census of Agriculture). Therefore, many farms meet the qualifications of a farm by the USDA definition, but offer a very small outlet for livestock manure. Hence, our survey relies on producers controlling a larger portion of land, making the decision to apply manure as fertilizer a more economically feasible alternative.

For many producers in Oklahoma, operations are not exclusive to only crop or livestock production. Few livestock production operations operate without land. Because many Oklahoma producers manage both crops and livestock, the third question sought to identify the number of producers that managed livestock along with their crops.

Gathering this information aids the researcher in identifying any potential correlation between willingness of a crop producer to accept or pay for manure and personal experience in managing livestock. The question asked producers to check any of the listed livestock that they managed. Over 80% of the respondents indicated that they managed cow-calf operations in addition to crops. Of the 289 usable survey responses, only 17 did not indicate some type of livestock management (5.88%). Yet, the only other livestock category that included more than 8% of the respondents was stockers at 54.3%.

Observing large numbers of cattle and few other types of livestock is typical of Oklahoma. As mentioned earlier, Oklahoma's winter wheat is a vital feedstuff for stocker and cow-calf operations. This combination works symbiotically by aiding in dispersing cash flows for producers throughout the year. Likewise, labor intensity for one operation occurs during the down season of the other operation, and wheat can produce hay for the next year's winter forage supply. The complete table detailing livestock managed follows in Table 2.

Table 2. Percent of Respondents Managing Livestock Types

Livestock Managed	Percent of Total
Cow/calf	80.6%
Stockers	54.3%
Cattle on Feed	6.9%
Dairy cattle	1.7%
Broilers	0.0%
Other poultry	0.7%
Swine	2.4%
Sheep	3.4%
Other	3.4%

Note: Producers were allowed to mark more than one category.

Yearly income is one of the most commonly asked questions in surveys due to its universal scope. Income variables clarify whether a representative sample has been obtained because everyone has income and it directly indicates an individuals' purchasing power. Therefore, the survey gathered respondents' household yearly income before taxes. As suggested by survey professionals, the income question was reserved for the end of the survey due to respondent sensitivity. To develop rapport and elicit honest responses, the survey reassured the respondent that her response would be "held strictly confidential." Primarily, this variable allows the researcher to observe correlation between Oklahoma producers' WTP for manure and their income. For example, some producers may be willing to pay more for manure because their income security allows the producer to "experiment" with the potential enhancing effects of manure. Some producers may view it as an entrepreneurial or innovative activity, while others view accepting manure as a detriment to the crop's potential productivity. The survey question follows in Figure 8, as it appeared in the survey.

> As close as you can recall, please estimate your household's yearly income before taxes by checking the appropriate box. This question is used to ensure our sample is representative of all Oklahoma producers. Please remember that your responses will be held strictly confidential.
>
> ☐ less than $20,000 ☐ $20,000-$39,999 ☐ $40,000-$59,999 ☐ $60,000-$79,999 ☐ $80,000 or greater

Figure 8. Annual Household Income Question

The average respondent's income is $68,870. 3.8% of respondents did not answer the question. Rather than consider these producers' incomes to be $0 and bias the household income estimate, only surveys whose respondents indicated an income range are considered in determining the average. In calculating the average, midpoints of the categories were assigned to incomes within the respective categories. As for the upper and lower bound categories, a value of $17,000 and $120,000 was assigned respectively. Because of the large number of respondents who indicated an income above $79,999, the researcher believes $120,000 represents all respondents in this category. Figure 9 represents the distribution of crop producer income.

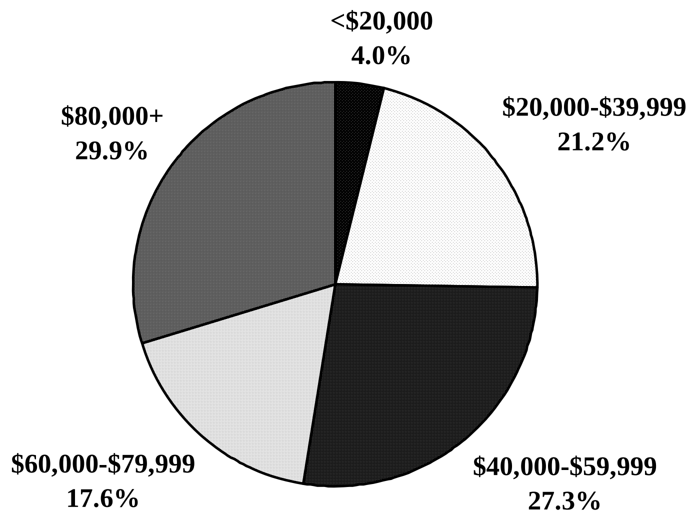

Figure 9. Annual Household Income

In this survey, household income is measured instead of farming income because it more accurately represents the purchasing power of a respondent. Income streams for agricultural families have changed over the last 25 years, and the majority of a family's income involved in agriculture no longer comes from farming. The Economic Research Service published in 2004 that off-farm wages and salaries actually totaled 55% of total farm household income. As a result, household income should better indicate the financial stability of the farm. In consulting the Economic Research Service report, the farm household income for 2003 was $68,483. This estimate closely resembles the survey estimate and suggests a representative sample of Oklahoma producers has been obtained. The next section discusses the numerous producer preference questions surrounding the contingent valuation question.

Crop Producer Experience and Preferences

Preceding the contingent valuation question, measuring producers' WTP, are three questions that clearly address the topic of the survey. The questions concern previous manure experience, preference for manure type, and application preference of the product. Demand theory states that product demand is a function of tastes and preferences, related product prices, product expectations, income, and population (Cramer, Jensen, and Southgate). Identifying these characteristics and measuring producers' WTP should help identify an inverse demand function for livestock waste. Thus, the remainder of the chapter seeks to obtain these indicators of demand.

The fourth question appears on the survey's second page and reads as follows.

> *Has livestock manure been applied to any crop or pasture acres you managed in the last ten years?*

The producer then has two potential responses: "Yes" or "No." Only 24.6% of producers indicate that manure has been spread on any acres they managed. This question designed to measure an individual's experience with manure, helps identify correlation between previous manure application and a crop producer's WTP for manure. Other studies reveal that previous experience or product knowledge significantly increases the adoption rates of technology. Koundouri, Nauges and Tzouvelekas, discussing technology adoption in irrigation, state that uncertainty associated with the adoption of any agricultural technology has two features: (1) the perceived risk of future farm yields after adoption, and (2) production or price uncertainty related with farming itself. Moreover, a study compiled by Nunez and McCann finds that decreasing uncertainty and increasing awareness of other producers using manure increases the probability of using manure.

Therefore, one is led to believe that previous experience with manure impacts a producer's decision to adopt manure as a substitute for fertilizer.

Following the experience question, the survey introduces more complex and detail specific questions. These decisions are designed to emulate decisions encountered in a real market transaction. The next question seeks to determine whether manure form significantly influences a producer's decision to purchase. The question appears as follows.

> *Livestock manure can be applied as solid manure or liquid manure. Assuming the costs to you were the same, if you allowed livestock manure application to crop acres under your management, which manure form would you prefer?*

Respondents indicate that 55.0% do not prefer a manure form. However, of those who do indicate a preference, 60.5% prefer solid form to liquid. Though the reasons for this preference are not clear, it may rely on the perception that dry manure is less odorous, easier to handle, and contains less water resulting in a more accurate nutrient content.

The next question measures a producer's preference for surface or subsurface application. Knowing that soil incorporation (subsurface) is more inclusive and expensive, the survey tests if a majority of crop producers prefer incorporation, something that could potentially increase the cost of application to livestock producers. Although this variable is a part of the contingent valuation question, an effort to measure this variable separate of other factors could specify whether the type of application is a major determinant in the willingness-to-pay decision.

As expected, the survey finds that the majority of producers prefer incorporation. A couple of reasons support producers' preference for manure incorporation. The first is to capture as many nutrients as possible. By burying these nutrients in the soil, they are less likely to migrate from the application site following a rain. This not only reduces the loss of nutrients to the atmosphere but also helps to control water pollution. Soil microorganisms aid in the second benefit by accelerating the decomposition of complex nutrients found in manure. For this reason, manure requires an extended period for nutrient release when compared to chemical fertilizer.

In the survey, producers are asked to assume that application costs remain the same despite the type of application. By holding cost constant, the survey can determine a producer's true preference and more accurately predict her behavior during a real market transaction. Below in Figure 10 is the question as it appeared in the text and a graphical representation of the survey responses.

> *Livestock manure can be incorporated into the soil by either tilling the soil after surface application or through manure injection. Assuming the costs to you were the same, if you allowed livestock manure applications to crop acres under your management, would you prefer soil incorporation?*

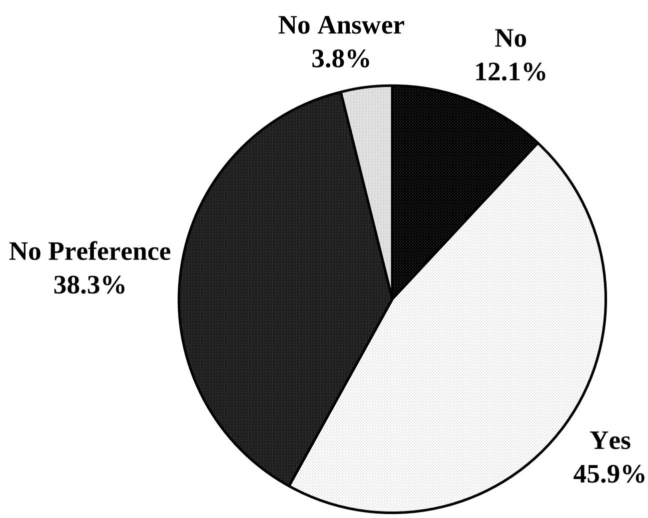

Figure 10. Preference for Incorporation of Livestock Manure

One concern is the percentage of individuals who did not respond to the question. It is somewhat difficult to determine why producers chose to not answer this question.

Speculation suggests that the complexity of the situation discourages producers from considering the possibilities. Alternatively, producers may desire more information before feeling they can make a knowledgeable decision.

The third page of the survey included another question measuring producer preferences. This question follows the contingent valuation section because it helps prevent respondents from becoming complacent in answering questions of the same nature. Question 10 asks crop producers that would allow manure application to identify any timing restrictions they would place on when livestock operators could spread manure. Respondents choose between four responses, selecting the one best describing the crop producers' timing preference for manure application. The most common restriction, favored by 76.5% of respondents, is for applications to follow harvest and conclude prior to planting. One explanation for application to occur over stubble or barren ground is that manure offers a greater chance than chemical fertilizer of covering or matting a crop and inhibiting the photosynthesis process. Additionally, applying manure between crops allows producers, who prefer the manure to be incorporated, to immediately work the ground and reduce the loss of nutrients from nitrogen volatilization and runoff. Only 10.7% of producers indicate a preference for manure application during the growing season, assuming application does not interfere with crop growth. Another 9.0% do not indicate any restrictions for when manure can be applied. Alternatively, 7.3% either do not answer the question or mark the "Other" selection.

Measuring Preference for Manure Attributes

The contingent valuation question measuring a producer's WTP for manure is the seventh question of the survey and appears on the third page of the survey booklet (See Appendix I). Placing the most difficult and important question late in the survey achieves two purposes: (1) previous questions effectively inform the producer of potential decision factors to stimulate a calculated response and (2) the respondent is less likely to become discouraged and discontinue the survey due to question difficulty because of the time already invested. This question is the primary reason for the survey, and it is carefully designed to minimize any bias and ensure all producers thoroughly understand the situation. This section details efforts to minimize the phenomenon of hypothetical bias that require the meticulous design. Meanwhile, other components of the contingent valuation question are emphasized.

Assuming few producers apply manure to their land, the survey asks the respondents to suppose that their cropland has traditionally received only commercial fertilizer. As verified earlier, more than 75% of responding producers have not received livestock manure in the past ten years. Designing the question in this way allows three-fourths of producers to simplify the hypothetical situation. They can consider their own production operation and focus on only how price and manure attributes affect their decision.

Within the question, five variables are randomly assigned to each survey. The five manure attributes varied randomly across surveys include the type of manure, type of application, manure form, fertilizer savings per acre, and the price a producer is asked to pay for the manure. For simplicity, only swine and poultry manure are considered in the survey. The reason for selecting these two manure types is that swine and poultry are the two livestock industries in Oklahoma that will be most affected by the Environmental Protection Agency's CAFO Rule. Because stockers and cow-calf operations typically avoid confined animal feeding operation regulations, waste management is less of a concern to the Oklahoma beef sector.

The type of application varied in the contingent valuation question is manure incorporation or no incorporation. Though this variable is measured individually, including this variable in the question allows the researcher to observe interaction between the other variables. One may note that the survey does not specify whether incorporation will occur at the time of application or following application. However, one can infer that an application of solid manure would require some type of soil tillage to complete incorporation. Manure in the liquid state can be incorporated using a specialized applicator at the time of spreading without soil tillage.

The form of manure is also varied in the survey. Two forms are observed in the survey: liquid or solid. Because chicken manure is naturally solid, it is presented in the solid form, without exception. As for swine manure, form is observed as both solid and liquid. Traditionally, Oklahoma swine operations utilize lagoons systems for storing waste. As a result, the most common form of swine manure is liquid because water is used as a vehicle to wash facilities and transport manure to a holding facility. However, technology is allowing some operations to separate manure from water. This allows facilities to offer swine manure in the solid form and justifies the use of solid manure in the survey.

The savings per acre variable consists of two observable values: \$10 or \$20. Savings are considered the reductions in commercial fertilizer costs to the crop producer by substituting manure for commercial fertilizer. The savings are determined in each survey using an equal probability (50%-50% chance) of observing either \$10 or \$20, specifying the savings in chemical fertilizer and helping a survey respondent to more easily comprehend the fiscal benefits of spreading manure. This encourages the producer to recognize savings as a positive manure attribute and determine a personal value for the manure. Assuming a fixed amount of savings also eliminates the need for the researcher to define the nutrient content of manure and the subsequent application rate. Speculating that savings to crop producers is a large determinant in willingness-to-pay, a range of manure prices is associated with each savings value.

Determining the price for manure is based on many considerations. In rationalizing how to determine a crop producer's WTP, the study assumes that all crop producers represent one of three categories. For some producers, their willingness-to-pay exceeds \$0, and they pay a positive price to have manure applied to their cropland. For others, willingness-to-pay is equal to \$0, indicating that the crop producer allows manure application, but is unwilling to pay for the product. The final group's willingness-to-pay value is less than \$0. In other words, individuals belonging to this group have to receive a per acre payment before accepting manure.

The most important consideration for determining a price range is the savings. One can assume that few producers are willing to pay a price for manure that greatly exceeds their savings. Therefore, the upper bound price a crop producer could be asked to pay is \$5 greater than total savings. For example, if a producer is assigned a savings of

$10 per acre in commercial fertilizer cost, the highest price any one survey can reveal is a price of $15 per acre. Likewise, a lower bound value is established. The lower bound value considers that many producers may refuse to have manure applied to their acres unless compensated. Many producers associate manure with negative externalities (pathogen transmission, weed seed, soil compaction, foreign material such as rocks, etc.). As a result, some surveys ask crop producers if they would be willing to accept manure if the livestock producer paid $X per acre to spread manure on the cropland. Adding this survey component allows the study to determine the number of crop producers requiring compensation prior to manure application on their cropland. These survey prices are recorded as negative numbers, indicating a negative price observed by the livestock producer. In summary, the range of prices that a survey realizes if the savings are determined to be $10 per acre is between $-10 and $15 per acre. Likewise, surveys assigned a savings of $20 per acre have a price range between $-10 and $25 per acre. Survey prices are observed as integers and randomized using a uniform distribution.

In terms of response, producers can mark "Yes," "No," or "No Answer." Theoretically, if a producer marks "Yes" then one concludes that a crop producer would allow manure spreading, subject to the product attributes and price described in the survey. Realize that some producers are asked if they would receive manure if paid a price. Therefore, a "Yes" response characterizes both the producer that is willing to pay for manure as well as the producer that is being paid to accept the manure. Similarly, a "No" response includes both producers who are not willing to pay $X per acre for manure and those who would not allow spreading despite being paid. As suggested by Creative Research Systems, the third response, "No Answer," is offered for producers who cannot make a decision. Creative Research Systems suggests that by offering "Don't know" or "No Answer" responses, the survey administrator avoids frustrating respondents and making them feel they are being forced to respond without adequate information. Further, research finds that once a respondent becomes frustrated, she is less likely to continue answering a survey. Figure 11 presents the contingent valuation question as it appears in the survey.

> Suppose your crop has traditionally received commercial fertilizer but no livestock manure. You now have the opportunity to let a nearby producer apply **swine** manure to your crop. With the **swine** manure application, you would not need to apply commercial fertilizer and would save **$20** per acre in commercial fertilizer costs. The manure is of the **liquid** form and is **incorporated** into the soil.
>
> If the livestock producer offered to **pay you $6** per acre to apply manure to your crop, would you accept the offer?
>
> ☐ Yes ☐ No ☐ No Answer

Figure 11. Contingent Valuation Question
Note: Variables randomly varied between surveys are **bolded** in this figure to more easily observe placement and order.

Sixty-three percent of surveyed individuals responding to the survey indicate that they would accept their offer detailed in the survey. A skeptic may believe that only individuals paid to accept manure responded with "Yes." However, 74 of the 182 affirmative respondents accept the offer despite being asked to pay $X per acre. One caution in analyzing this data is the potential for hypothetical bias. Though measures are taken to eliminate the problem in the estimation process, the above statistics are not corrected for hypothetical bias. The following section will discuss methods implemented to reduce hypothetical bias and the potentially misleading conclusions.

Eighteen and six-tenths of respondents decline the hypothetical offer and another 18.3% decline to answer the question. A question immediately follows asking those individuals who checked "No Answer" to indicate from a list the response that best described their reason for not answering. The list includes four responses. The first is that a respondent cannot distinguish between "yes" or "no." The next response is that an individual does not have enough information to make the decision. Thirdly, the individual indicates a preference for some other type of mechanism for making the decision, and the last response is "Other" in which the respondent is then prompted to explain.

Of the 53 producers who mark "No Answer," 49 proceed to indicate why they do not make a decision. Nearly 90% of these producers said they need additional information to make the decision. This high percentage unable to make a decision helps assure the researcher that biased data is being avoided. In other words, it is unrealistic to assume that in a real market transaction the given information would be sufficient for all crop producers to make a decision.

In addition to "No Answer" respondents, a number of individuals who select "No" on the contingent valuation question also proceed to answer this question. Nearly 49% indicate that they also choose "No" due to insufficient information. 34% indicate "Other" reasons. This is promising for the livestock producer because it suggests that potentially an even larger market may exist for manure if crop producers are provided with additional information. However, to maintain conservative estimates, speculation about the possibility of a market greater than what our survey data indicates will be considered no further.

Removing Hypothetical Bias

As previously mentioned, hypothetical bias can significantly decrease the validity of research results. This section details the methodological procedures employed by this survey to remove bias. The first objective of the survey is to provide an introduction to the producers detailing the survey objectives, background information to help the producer understand the importance and need for the survey information, a form of contact, and the approximate time required to complete the survey. Providing the respondent with this information not only develops rapport, but also helps to ensure that producers base decisions on information and not biased perceptions. However, the two most important components in reducing hypothetical bias and providing conservative estimates include a cheap talk script and calibration mechanism.

Recall that hypothetical bias occurs when subjects overestimate their true value of a good. Champ and Bishop describe the source of bias as respondents who have positive feelings toward a project or good but do not purchase in a real market. Realizing this has represented the Achilles heal of contingent valuation, several procedures are implemented in this study to avert the problem.

Cheap talk is a concept that reminds respondents of their natural tendency to overestimate WTP in a hypothetical market situation. Numerous studies reveal that stated willingness-to-pay values are significantly lower in surveys where cheap talk is used. As will be observed, a brief cheap talk script precedes the contingent valuation question in effort to reduce crop producers' WTP. Below in Figure 12 is the cheap talk script as it appears in the survey. As discussed in the literature review, Lusk and

Cummings and Taylor have significant findings to indicate cheap talk is effective at reducing hypothetical bias, especially when the audience is unfamiliar with the product. Though cheap talk is effective at reducing hypothetical bias, many argue that cheap talk does not entirely eliminate hypothetical bias. Thus, a second strategy referred to as calibration is employed *ex-post* to the contingent valuation question.

> *In the next question, we would like you to tell us how you feel about substituting livestock manure for commercial fertilizer. Studies have found that people tend to overestimate their willingness to accept or pay money in hypothetical situations. When answering the question, please consider how you would react if you actually had to pay or accept real money that could be used for other goods and services.*

Figure 12. Survey Cheap Talk Script

Calibration is another form of bias reduction that attempts to measure how certain the individual is that her stated behavior would be the same in a true market setting. In other words, how closely does her hypothetical behavior represent her true behavior? In the case of this survey, a ten-point Likert scale is employed. If a respondent replies with "Yes" to the contingent valuation question, she is then directed to circle a number from one to ten, (1 representing very uncertain and 10 representing very certain) to indicate how likely she would make the same decision if the transaction involved real money.

Champ and Bishop reveal that using individuals' certainty to recode responses is very effective at reducing hypothetical bias. For example, if a crop producer responds that they accept manure and then choose a certainty level below the defined threshold, the response is recoded to "No" for statistical estimation.

One problem experienced in calibration is the subjectivity of a certainty threshold. Numerous studies compare revealed preferences to stated preferences. Though an absolute threshold value has not been determined to serve as a benchmark, research indicates that employing a certainty level of eight eliminates hypothetical bias. Previous studies find that a threshold of eight either will produce unbiased value estimates, or will underestimate true values. Thus, the use of the certainty-calibration provides a conservative value estimate. Using cheap talk and calibration can help to develop two data sets. Calibrated data conservatively estimates WTP, whereas the uncalibrated data set likely overstates WTP. Therefore, the use of calibrated and uncalibrated data sets should provide a lower and upper bound to the true willingness-to-pay values (Norwood). Take a moment to observe how this strategy has influenced our survey data. Recall that before any calibration technique, 182 survey respondents said they would agree to the offer. After calibrating uncertain "Yes" responses to "No" responses, we find that only 119 respondents would theoretically exercise their specific survey scenario in a real market. As you can see, this one tool reduces the percentage of surveyed individuals who indicate they would agree from 63.0% to 41.2%.

Summary

The intention of this study is to determine and assess the effects of the Clean Water Act regulations on Oklahoma livestock producers. Because many livestock producers will have to export manure from their facilities to become regulation compliant, this study seeks to determine the size, scope, and characteristics of the manure market by collecting data about Oklahoma crop producers. More specifically, a survey tool is designed to measure Oklahoma crop producers' willingness-to-pay for livestock manure.

The survey pool of 512 crop producers generates 289 useful responses. Of the crop producers surveyed, at least one out of every two respondents managed winter wheat for grazing, dual-purpose wheat (grain and grazing), pasture and other hay (non alfalfa). Farmers are involved with other crops such as corn, barley, rye, peanuts, soybeans, and cotton, but to a much smaller degree. Because of Oklahoma's strong beef cattle presence, 80.6% of the crop producers are also involved with cow-calf operations.

The survey employs both cheap talk script and certainty calibration to reduce the problems associated with hypothetical bias in contingent valuation studies. Absent calibration techniques, 63.0% of crop producers indicate that they would accept the survey offer and allow manure spreading. With calibration, only 41.2% participate. Preliminary indications suggest that many livestock producers could export manure to neighboring crop producers given the commercial fertilizer savings indicated in the survey. However, to this point, three-fourths of crop producers have not spread manure on any of their cropland in the last ten years. Though the large majority of crop producers are inexperienced with manure, the study measures demographical and preferential characteristics to predict the likelihood that a crop producer will participate in a realistic market.

The next chapter develops the random utility model and incorporates producer preferences and manure attributes into the model. Following the theory of maximum likelihood, interpretation of the results informs the livestock producer about preferred manure attributes and the probability of crop producer acceptance.

CONCEPTUAL CONSIDERATIONS

Federal regulations could force livestock producers to seek off-farm acres on which to apply manure. This research seeks to inform livestock producers about potential alternatives to reduce compliance costs. Specifically, this study estimates Oklahoma crop producers' willingness-to-pay (WTP) for manure as a commercial fertilizer substitute. Using contingent valuation, the distribution of WTP across producers is estimated, as well as the impact of manure attributes and demographics on WTP.

As previously discussed, one of the major problems determining the substitution value of livestock manure for commercial fertilizer is the absence of data detailing manure market transactions. To estimate compliance costs for livestock producers, data are necessary that details the market value of manure. In absence of market data, a hypothetical market is established to determine crop producers' preferences for livestock manure and estimate crop producers' willingness-to-pay.

The chapter revisits the contingent valuation question design and modeling willingness-to-pay under random utility theory. Next, the chapter includes the development of the maximum likelihood estimation procedure. Finally, procedures allowing the researcher to provide information to livestock producers about favorable manure attributes are discussed.

Determination of Willingness-to-Pay

Recall the contingent valuation question discussed in the preceding chapter identified the context of the question and specific manure attributes. Remember that contingent valuation is widely used for its flexibility in eliciting data for estimation procedures and placing monetary value on goods and services not regularly bought and sold in the marketplace. As a result, this modeling procedure allows the researcher to generate numerous scenarios where respondents indicate their preferences by responding to a dichotomous choice question. Specifically, the respondent is presented with a hypothetical purchasing opportunity and is asked whether she would make the purchase.

The purchasing opportunity described varies according to four dummy variables: fertilizer savings, manure incorporation, livestock type, and physical form of manure. Producers observe a savings of $10 or $20 per acre in commercial fertilizer costs; the manure is either incorporated or broadcast; the producer either receives swine or poultry manure; and the respondent observes manure of either liquid or dry form. Following the described scenario, the survey asks the individual if she would be willing to pay the stated price.[11] This price serves as the indicator for the producer's actual willingness-to-pay. Suppose that a producer's WTP is composed of two parts: one is an observable component (a function of four explanatory variables) and the other is random and unobserved. Using this design, the researcher models producer *i*'s decision with the following utility function by substituting WTP for utility using a money-metric assignment:

[11] The price observed by a respondent can be either negative or positive. In the case of a positive price, the producer is asked to pay the stated amount to receive the manure. A price is considered to be negative when the producer is asked to accept the manure for a payment (i.e. The livestock producer pays the crop producer to take the manure.).

(2) $$WTP_i = X_i\beta + \varepsilon_i$$

where WTP_i represents the true manure value, X_i is the vector of explanatory variables, β is a conformable vector of coefficients, and ε_i represents the unobserved WTP component for individual *i*. The first component of the formula is the $X_i\beta$ matrix. Because we observe an individual's WTP as a function of individual manure attributes, $X_i\beta$ can be expressed as a linear combination of manure attributes. Consider the following example:

(3) $$X_i\beta = \beta_1 + \beta_2[savings_i] + \beta_3[liquidswine_i] + \beta_4[dryswine_i] + \beta_5[incorporation_i],$$

where *savings* represents a dummy variable where the variable takes the value of one for \$20 in fertilizer savings and zero for savings of \$10. This implies that the intercept, β_1, will represent the coefficient for \$10 in fertilizer savings when all other explanatory variables are held constant in the equation. The variables *liquidswine* and *dryswine* represent the dummy variables for liquid swine manure and solid swine manure with dry poultry manure serving as the reference group. Dry poultry manure's coefficient would then be observed within the intercept coefficient, ceteris paribus. The last variable, *incorporation*, is a dummy variable assuming a value of one if the livestock producer incorporates the manure into the soil, and zero otherwise.

The second term of WTP, ε_i, is assumed to be normally distributed and accounts for any random noise and explanatory variables not measured within the study. In other words, this pricing component represents all other unnamed factors that affect a crop producer's decision to purchase livestock manure. Under these assumptions, WTP is linearly expressed in the following way.

(4) $WTP_i = \beta_1 + \beta_2[savings_i] + \beta_3[liquidswine_i] + \beta_4[dryswine_i] + \beta_5[incorporation_i] + \varepsilon_i$

We can now introduce the theoretical framework of maximum likelihood to obtain coefficient estimates. Intuitively, a crop producers' decision to purchase occurs when her utility from the product exceeds the cost provided in her survey. In other words, a producer decides to purchase manure when her willingness-to-pay exceeds the price, P_i. Recall that a producer's response is observed by means of a dichotomous choice question. Therefore, a producers' WTP is made evident through the discrete indicator variable, I_i, such that

(5) $$I_i = 1 \text{ if } WTP_i > P_i, \\ = 0 \text{ otherwise.}$$

Assuming the error term is normally distributed, the following statement is made about the probability of observing a "Yes" response.

(6) $$\begin{aligned} \Pr(I_i = 1) &= \Pr(WTP_i > P_i) \\ &= \Pr(X_i\beta + \varepsilon_i > P_i) \\ &= \Pr(\varepsilon_i > P_i - X_i\beta) \end{aligned}$$

The probability of observing a "Yes" response is expressed where unexplained variation, ε_i, is greater than the crop producer's observed price, P_i, less the $X_i\beta$ term. Likewise, a "No" response, where $I_i = 0$, is represented by Equation 7.

(7) $$\Pr(I_i = 0) = \Pr(\varepsilon_i < P_i - X_i\beta)$$

If the researcher allows $\Phi(x)$ to denote the standard normal cumulative distribution function of all survey responses, then, Equations 6 and 7 are written as

(8) $$\Pr(\varepsilon_i > P_i - X_i\,\beta) = \Phi\left(\frac{X_i\beta - P_i}{\sigma}\right)$$

(9) $$\Pr(\varepsilon_i < P_i - X_i\,\beta) = 1 - \Phi\left(\frac{X_i\beta - P_i}{\sigma}\right)$$

where σ represents the standard error of ε_i.

Implementing these two equations allows the researcher to construct a maximum likelihood estimator. This estimation procedure will determine the β matrix and variance of the ε_i. The probability of observing the i^{th} survey response, given β and σ, is

(10) $$L\left(\beta_k, \sigma \mid X_i, I_i, P_i\right) = \left[\Phi\left(\frac{X_i\beta - P_i}{\sigma}\right)\right]^{I_i}\left[1 - \Phi\left(\frac{X_i\beta - P_i}{\sigma}\right)\right]^{1-I_i}$$

Maximum likelihood estimation then entails choosing the β and σ that minimizes

(11) $$\ln\left(L\left(\beta_k, \sigma \mid X_i, I_i, P_i\right)\right) = \sum_{i=1}^{N}\left[I_i \ln\left(\Phi\left(\frac{X_i\beta - P_i}{\sigma}\right)\right)\right] + \left[(1 - I_i)\ln\left(1 - \Phi\left(\frac{X_i\beta - P_i}{\sigma}\right)\right)\right]$$

for the entire sample. Equation 11 is referred to as a log-likelihood function. One should also note the following characteristics of maximum likelihood estimators. Estimates are consistent, asymptotically normal, efficient, and progress toward a normal distribution centered around the true parameter value in large sample sizes (Maximum Likelihood Procedures).

Coefficient Interpretation

In regard to this type of willingness-to-pay model, Cameron and Quiggin explain that willingness-to-pay models predict the probability an individual is willing to pay a specific price for a product. Each survey assigns an arbitrary price to be interpreted as a threshold value. Measuring this variable across a large number of surveys allows the researcher to use the price as an explanatory variable. The researcher uses the producer's response to the question and associates the threshold value with producer characteristics, manure attributes, and answers from similar respondents. This allows the researcher to employ a likelihood estimation procedure and estimate the average WTP for the entire population under certain circumstances and producer characteristics. Though the model does not allow the researcher to determine the exact threshold for each individual, all observations combined allow an average WTP to be established. Computing this value is similar to a weighted average such that, $\Sigma p_i t_i$ where p_i is the probability that respondent i will pay the threshold price t_i. One advantage this approach offers is that the greater the number of explanatory variables gathered in the study and the greater the number of respondents, the more accurate the researcher can estimate the true WTP value for the population.

After the β coefficients are estimated, one can predict the percentage of producers likely to accept manure application at any price level. To accomplish this task, coefficients are inserted into Equation 4 to estimate the average price that crop producers are willing to pay for manure under a specific set of attributes.

Intuitively, model estimates allow the researcher to make the interpretations about crop producers' WTP. For example, assume that 50% of the respondents who were asked to pay $5 per acre for manure replied "Yes" and the other 50% replied "No." Therefore, on average, the WTP is equal to $5 per acre. Similarly, if more than 50% respond "Yes," then the average WTP is greater than $5 per acre. The same can be said for negative responses. If "No" responses exceed 50%, then WTP for manure is less than $5 per acre.

The researcher can also analyze each attribute individually to determine how the specific attribute affects the manure price. For example, if we assume that only manure form is varied and all other explanatory variables are held constant, then the premium for solid manure over liquid manure can be determined, provided crop producers' WTP. Assume that the average respondent's WTP for liquid manure is $4 per acre in comparison to $6 per acre for dry manure. Hence, the researcher concludes that the average crop producer is willing to pay a $2 premium to have dry manure over liquid manure. This rational can be applied to the interpretation of all variables. However, one must realize that this interpretation restricts an individual to analyzing only one variable at a time while all others variables are held constant.

This study uses a number of dummy variables to determine the correlation between willingness-to-pay and specific manure attributes. Let us take a moment to explain the interpretation of coefficients for dummy variables. After the willingness-to-pay coefficients are estimated, the researcher can estimate the price at which a producer would have the highest probability of paying. Hill, Griffiths, and Judge note that intercept dummy variables are additive. In other words, the quantitative value observed for a variable omitted from the estimation as part of the reference group is added to the regression intercept. Consider Equation 4 in the previous section. If savings are assumed to be $10 per acre, then β_2 is equal to zero and the quantitative value for $10 in savings is observed in the regression intercept. Figure 13 provides the willingness-to-pay equation with described manure attributes. Notice that the researcher progressively describes a situation in which the beta coefficients are equal to zero and the qualitative value for the attribute is observed by the intercept coefficient.

$$
\hat{\mathrm{WTP}} = \begin{cases} \beta_1 + \beta_2 + \beta_3 + \beta_5 & \text{\$20 savings, liquid, swine, incorporated} \\ \beta_1 + \beta_3 + \beta_5 & \text{\$10 savings, liquid, swine, incorporated} \\ \beta_1 + \beta_4 + \beta_5 & \text{\$10 savings, dry, swine, incorporated} \\ \beta_1 + \beta_5 & \text{\$10 savings, dry, poultry, incorporated} \\ \beta_1 & \text{\$10 savings, dry, poultry, non-incorporated} \end{cases}
$$

Figure 13. Estimated Willingness-to-Pay for Alternative Manure Attributes

The next chapter expands on the discussed theoretical concepts and provides insight to producers and policymakers about crop producer preferences and marketing alternatives through analysis of the results. Beta and variance estimates are analyzed to determine the marginal effects of demographical and experience variables on crop producers' willingness-to-pay. The chapter concludes with a cumulative distribution function estimating the percentage of producers who would purchase manure at a given price.

EMPIRICAL RESULTS

The cost for livestock producers to comply with governmental regulations depends on the ability to export manure to off-farm acres. By selling manure for a positive price to a large majority of crop producers, livestock producers can buffer themselves from the cost of compliance. This chapter uses the data discussed previously to estimate the value of manure as perceived by crop producers. The following results are generated from 289 survey responses obtained from Oklahoma crop producers.

The primary objective of this study is to help researchers better estimate compliance costs to animal feeding operations under governmental regulations by observing the factors affecting a crop producers' decision to purchase manure. To accomplish this task, the researcher considers factors such as regional dispersion, income, farm size, and management practices. Collectively, the research results contribute to the academic knowledge by helping determine if a viable market exists for manure to provide offsetting cash flow to compliance costs.

The results in this chapter are obtained by employing an unconstrained optimization algorithm in MATLAB to minimize the log-likelihood formula, Equation 11, in the previous chapter. With the use of contingent valuation under a random utility framework, the researcher measures the influence of several factors on crop producers' willingness to use livestock manure as a commercial fertilizer substitute. In the following sections, several models are used to identify specific purchasing behaviors. A brief chapter outline includes identifying the variables measured and discussing organization of the agricultural industry, briefly revisiting the estimation tool and hypothetical bias reduction techniques, discussing models and hypothesis test significance, and developing a cumulative distribution of willingness-to-pay.

Data and Estimation

Estimating the willingness-to-pay of crop producers is the major purpose of this study. Numerous survey tools are involved to ensure that the results are representative of crop producers' true willingness-to-pay (WTP). In doing this, clarifying the steps and data used in the estimation process is imperative to inform the reader of this study's procedures. Let us briefly revisit the information collected from survey respondents. Demographically, the survey mechanism reveals information about the Oklahoma farming situation and producer practices. The researcher discovers many facts about crop producers to potentially explain deviations in WTP. In surveying the crop producers of Oklahoma, more than 94% of the crop producers also managed livestock under diversified operations. This characteristic is somewhat unique with respect to other agricultural states in that Oklahoma is comprised of starkly different land and soil types. Different from Midwestern states primarily assigned to crop production and Western grazing states, Oklahoma's different soil types promote diversified livestock and crop operations.

Recall that the survey's main question focuses on identifying a willingness-to-pay value for the average crop producer based on manure attributes. Before analyzing the models, it is important to clarify the variables and any manipulation performed on the original data set. Table 3 highlights the variables used in the estimation procedures and the respective survey question prompting the information.

A couple of tools are being implemented to correct hypothetical bias. One method employs a certainty calibration technique that produces two individual data sets; one calibrated and the other uncalibrated. Both of these data sets are also under the influence of a cheap talk mechanism administered during the survey. Individually, these tools have been demonstrated in numerous studies (Lusk, Champ and Bishop, Cummings and Taylor, and Cameron and Quiggin) to produce relatively unbiased estimates of true values. In fact, these mechanisms provide two biased data sets, creating a lower and upper bound of the true values as suggested by Norwood. The calibrated data with cheap talk influence likely biases the results in the direction of underestimating a crop producer's WTP. The uncalibrated data set likely produces a biased set in the direction of overestimating crop producers' WTP.

Another remark about the data are the exclusion of observations. Within some surveys, producers chose to not answer specific questions. For instance, several chose not to identify an income range. Because one cannot predict the income of these individuals, this requires the observations to be omitted from the data set to prevent any bias. In these instances, the sample size will be less than 289.

Table 3. Survey Variables

Survey Question	Variable Name	Description
Has livestock manure been applied to any crop or pasture acres you managed in the last ten years	*Experience*	1 if “Yes”, 0 otherwise
How many crop or pasture acres do you currently manage (Data are scaled according to maximum category)	*Acres*	0.2 if 0-499 acres 0.4 if 500-999 acres 0.6 if 1,000-2,999acres 0.8 if 3,000-9,999 acres 1.0 if 10,000+ acres
Contingent Valuation Question: Variables randomly predetermined for survey respondent	*Savings*	1 if savings is \$20 per acre of commercial fertilizer, 0 if savings is \$10 per acre
	Incorporation	1 if manure is incorporated, 0 if not incorporated
	Drypoultry	1 if manure is solid and poultry, 0 otherwise
	Dryswine	1 if manure is solid and swine, 0 otherwise
	Liquidswine	1 if manure is liquid and swine, 0 otherwise
Price producer is asked to pay in survey	*P*	-10, -9, -8, …23, 24, 25
Estimate your household’s yearly income before taxes (Data are scaled according to maximum category)	*Income*	0.2 if less than \$20,000 0.4 if \$20,000-\$39,999 0.6 if \$40,000-\$59,999 0.8 if \$60,000-\$79,999 1.0 if \$80,000+
Regional location determined by respondents’ mailing address	*Southeast*	1 if south of I-40 and east of I-35, 0 otherwise
	Southwest	1 if south of I-40 and west of I-35, 0 otherwise
	Northwest	1 if north of I-40 and west of I-35, 0 otherwise
	Northeast	1 if north of I-40 and east of I-35, 0 otherwise

Note: Chapter 3 includes an in-depth discussion of the survey and all variables obtained.

Before beginning the modeling process, we should clarify the information that coefficient estimates produce and how they are interpreted. Observe that many variables in Table 3 are dummy variables. These variables allow a researcher to express qualitative characteristics of the respondents in binary form. Therefore, dummy variables require an altered interpretation of the coefficients relative to other explanatory variables (Hill, Griffiths, and Judge). Collectively, all estimates reveal two things about a variable. First is the sign of the coefficient; this suggests whether an attribute negatively affects a crop producers' WTP or if it positively affects WTP. Secondly, the magnitude of a coefficient indicates how significantly the variable affects WTP. Where interpretation differs for dummy variables is the signs and magnitudes are relative to variables contained within the reference group. As discussed in the previous chapter, if all dummy variables for a category are included in the estimation of the model, perfect collinearity occurs. To alleviate this problem, a dummy variable for a single category is omitted, which then defines a reference group. As it is so called, the estimated coefficients then represent differences relative to this group.

Consider the three types of manure observed in the survey: *dryswine*, *liquidswine*, and *drypoultry*. Because these three variables are exhaustive in representing each type of manure in the survey, if all were included in the model estimation, the manure variables would be an exact linear combination of the intercept variable, $x_1 = 1$. This would lead to a misspecified model. By omitting *drypoultry*, the coefficients of *liquidswine* and *dryswine* are relative to *drypoultry* that is now part of the reference group. In the case of all dummy variables in this study, they will be intercept dummy variables. This implies the parallel shift of the function is a result of including *drypoultry* in the reference group and captures the effect on a crop producer's WTP. One must also recognize that intercept dummy variables are additive. As more variables become a part of the reference group, parallel shifts of the intercept will take place to adjust for the respective variable's effect on WTP (Hill, Griffiths, and Judge).

In the case of insignificant variables, realize that two interpretations will take place. For dummy variables, insignificance (not statistically different from zero) suggests that the variable is not found to differ from the relative variable that is part of the reference group. For ordinary explanatory variables, insignificance suggests that the variable does not affect the average crop producer's WTP.

Savings Model

The first simple linear model estimates crop producers' willingness-to-pay using a modified probit model. The model is composed of only two variables, the intercept and the dummy savings variable, and yields the following model

$$\text{WTP} = \beta_1 + \beta_2[\textit{savings}] + \varepsilon \tag{12}$$

with fertilizer savings of $10 (*savings10*) serving as the reference group for the model.

We first observe in Table 4 that only the intercept of the uncalibrated model is significantly different from zero, based on the Wald test statistic. The insignificance of the savings coefficient implies that in both the calibrated and uncalibrated models, producers are not willing to pay any greater price to receive manure that saves them $20 in commercial fertilizer cost as compared to $10 in savings.

The uncalibrated model estimates WTP to be about $10. In contrast, the calibrated model implies that WTP does not significantly differ from zero. Using these two models to define the bounds of WTP indicates the average crop producer's WTP is in the range of $0 to $10. Studies such as Glewen and Koelsch and Metcalfe et al. seem to support the conclusion that WTP is somewhere between $0 and a slightly positive value. However, the researcher feels that including additional explanatory variables may generate greater evidence for a positive WTP of crop producers. The next model introduces variables observed by producers in the survey's contingent valuation question.

Table 4. Savings Influence on Willingness-to-Pay

	Uncalibrated Model	**Calibrated Model**
	Parameter Estimate (t-statistic)	
Intercept	9.7613***	-2.3107
	(3.6691)	(-1.0830)
Savings	0.6637	-0.6011
	(0.1983)	(-0.1954)
Standard Deviation of Error Term	21.3646***	19.7111***
	(5.3824)	(5.5526)

*, **, *** Indicate 10%, 5%, and 1% significance.
Log Likelihood Function Value: -175.0990 (Uncalibrated) and -178.7599 (Calibrated)
Sample size is 289.

<u>Baseline Model</u>

In Table 5, the researcher estimates four models accounting for manure characteristics. Uncalibrated and Calibrated Models – 1 include only variables observed in the contingent valuation question. These four variables are hypothesized to have the greatest influence on average WTP. Therefore, expectation for the model estimates is that they will share a much greater correlation with WTP and provide greater insight into the behavioral decisions of a crop producer. The model coefficients are obtained by estimating the following equation,

(13) $\text{WTP} = \beta_1 + \beta_2[\textit{savings}] + \beta_3[\textit{incorporation}] + \beta_4[\textit{dryswine}] + \beta_5[\textit{liquidswine}] + \varepsilon.$

Note that the reference group for this model is *savings10*, *noincorporation*, and *drypoultry*.

Table 5. Contingent Valuation Question Estimates

	Uncalibrated Model - 1	Calibrated Model - 1	Uncalibrated Model - 2	Calibrated Model - 2
	Parameter Estimate (t-statistic)			
Intercept	10.8016***	1.2307	9.9270***	-0.2494
	(2.8215)	(0.4427)	(2.5644)	(-0.0751)
Savings	0.7126	-0.7114	1.0049	-0.3850
	(0.2142)	(-0.2650)	(0.2999)	(-0.1502)
Incorporation	0.4107	-2.4123	0.5924	-2.0783
	(0.1189)	(-1.2038)	(0.3473)	(-0.7475)
Experience			3.4131	5.1315
			(0.8388)	(1.3915)
Dryswine	0.0582	-2.5637	0.0087	-2.8254
	(0.0139)	(-0.7362)	(0.0022)	(-0.7266)
Liquidswine	-3.7888	-4.6945	-3.9748	-5.0230
	(-0.9463)	(-1.2700)	(-0.9873)	(-1.3988)
Standard Dev. of Error Term	21.2477***	19.5215***	21.4750***	19.8125***
	(5.4127)	(5.5337)	(5.5822)	(5.9219)

*, **, *** Indicate 10%, 5%, and 1% significance.
Log Likelihood Function Value: -174.4669 (Uncalibrated 1) & -177.6304 (Calibrated 1)
Log Likelihood Function Value: -174.1003 (Uncalibrated 2) & -176.5869 (Calibrated 2)
Sample size is 289.

The second set of models adds a dummy variable for experience[12]. Studies conducted by Nunez and McCann and Koundouri, Nauges, and Tzouvelekas confirm that experience is a key determinant in purchasing a new good. Because of the renewed practice using manure as fertilizer, one expects experience to significantly influence WTP. The reference group for the model will remain the same as Equation 13, but will add *noexperience* to the group. The following equation represents the Calibrated and Uncalibrated models – 2.

(14) $$WTP = \beta_1 + \beta_2[\textit{savings}] + \beta_3[\textit{incorporation}] + \beta_4[\textit{experience}] + \beta_5[\textit{dryswine}] + \beta_6[\textit{liquidswine}\,] + \varepsilon.$$

The WTP models find that only the intercepts of the uncalibrated models are statistically significant. Again, savings is not shown to increase a crop producers' WTP.

[12] For explanation of this variable and others, refer to Table 3 at the beginning of this chapter.

Likewise, incorporating manure is not valued any more than topically applying manure. Initially, this seems to contradict the results of Question 6 in the survey (See Appendix I). The question asks respondents outside the context of contingent valuation about their preference for manure incorporation. 46.0% do prefer incorporation in comparison with only 12.1% that do not. The difference however is made up in the 38.4% who do not have a preference. Observing the large percentage of producers with no preference may suggest why incorporation does not appear to influence the average crop producers' WTP. One must also consider that incorporation is specific to the crop being fertilized. For crops such as pasture and planted grains, incorporation would not be preferred.

The next group of variables in the model is type of manure. Three types of manure are defined in the surveys: solid swine manure, liquid swine manure, or solid poultry manure. Manure type estimates across all four models indicate that no variable is different from zero. In other words, crop producers' WTP is not affected by the type of livestock manure or the form offered. One explanation for this behavior is that manure form may actually be specific to the type of crops or stage of crop growth at the time of manure application. For some producers, solid may be better for those desiring no incorporation and a slower nutrient release. However, if producers desire an application to a maturing corn crop, solid manure may result in matting and crop loss. Therefore, a premium may not exist for different manure forms, because preferred form is relative to the producers' given production situation.

Because Calibrated and Uncalibrated Models – 1 do not generate significant results, *experience* is added as an explanatory variable as it is hypothesized to increase a crop producer's WTP. Estimates in Table 4 indicate, however, that the variable is not significant in either the calibrated or uncalibrated models. Often, Wald test statistics are not the most accurate depiction of significance for variables estimated under a likelihood estimation procedure. Statistics offers many other approaches to test for coefficient significance on WTP, and one of those is the likelihood ratio test. Employing a likelihood ratio (LR) test on Calibrated Model – 2 allows the study to determine if *experience* affects WTP (H_O: β_4=0 vs. H_A: $\beta_4 \neq 0$). Maddala indicates that a likelihood ratio test is defined as $-2log_e\lambda$ and is distributed as a Chi-square with k degrees of freedom; where k is defined as the number of parameters being restricted and λ represents the maximum likelihood coefficient of the restricted model, $\hat{L}_R$, divided by the maximum likelihood coefficient of the unrestricted model, $\hat{L}_U$. Rearranging terms, the test is expressed as

$$\text{LR} = -2[\ln(\hat{L}_R) - \ln(\hat{L}_U)] \sim \chi^2_k \tag{15}$$

Using MATLAB to determine the likelihood function value of the restricted model, a *p*-value of 0.1486[13] is determined according to the LR test statistic. The hypothesis is not rejected because the *p*-value exceeds the chosen level of significance at 0.05, and supports the earlier conclusion that manure experience does not increase a crop producers' WTP. In addition to this test, numerous hypothesis tests can be conducted across several variables to determine the joint significance of variables influencing a crop producers' decision to accept application. Now, take a look at manure type and form in the Calibrated Model – 2 to see if the combined affects of *dryswine* and *liquidswine* estimates differ from zero (H_O: $\beta_4 = \beta_5 = 0$ vs. H_A: $\beta_4 \neq \beta_5 \neq 0$). The hypothesis is not

[13] The *p*-value of a hypothesis test is calculated by finding the probability that the *t*-distribution can take a value greater than or equal to the absolute value of the sample value of the test statistic (Hill, Griffiths, and Judge). In other words, if the *p*-value exceeds the chosen level of alpha, then the hypothesis is not rejected. The hypothesis is rejected if the *p*-value is less than alpha.

rejected with a *p*-value 0.1702, supporting the estimates of Table 5 that premiums do not exist for manure type and form.

In one final attempt to determine if the combined affects of the four variables, aside from savings and the intercept, differ from zero, a LR test is conducted (H_O: $\beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$ vs. H_A: $\beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$). At the 5% level, the hypothesis is rejected. This suggests that jointly, the variables differ from zero and describe some of the variation observed in crop producers' WTP. However, no individual manure attribute or producer characteristic is statistically strong enough to be detected individually. These models reveal little about the variation in crop producers WTP. It is surprising that form, type, experience, and savings are not significant given the raw statistics revealed by producers in Chapter 3. What can be said is that both sets of models estimate the WTP value to lie between \$0 and \$10. Unexplained behavior by producers may stem from the possibility that many producers are aware of the good, but are skeptical of its use in their systems. The greater probability is that the model does not account for a number of other explanatory variables driving crop producers' decision to purchase. Referring to the "Demand for Livestock Manure" section in Chapter 2 appears to support the idea that numerous factors determine demand for livestock manure. Given the large number of explanatory variables for manure demand, it may be that without an extremely large sample size, coefficient significance for a single variable will be difficult to detect. The next section analyzes at the demographic variables to identify any potential correlation with WTP.

Crop Producer Demographics

This section analyzes the effect of several demographic variables measured in the survey sample. The impacts of farm size, household producer income, and regional location on a crop producers' WTP are measured. Models employ the use of both calibrated and uncalibrated data to develop lower and upper bounds for WTP. Provided the lack of explanatory power from manure attributes, the researcher is looking to determine if demographical factors are highly correlated with a producers' decision to purchase manure.

Household Income

This model identifies the effects of a producer's income on WTP. Table 6 includes parameter estimates for four models. The first two models consider savings and income in the linear form. Recall from Table 3 that income is scaled according to the maximum category. Therefore, the salary for an individual earning less than \$20,000 is assigned a value of 0.2 and those greater than \$80,000 is equal to one. As mentioned earlier, the sample is reduced to 278 because 11 respondents did not indicate an income range during the course of the survey. The first two models are represented by the following equation.

$$(16) \qquad WTP = \beta_1 + \beta_2[savings] + \beta_3[income] + \varepsilon$$

where the reference group is only *savings10.*

Table 6. Income Effect on Crop Producers' Willingness-to-Pay

	Uncalibrated Model - 1	Calibrated Model - 1	Uncalibrated Model - 2	Calibrated Model - 2
	Parameter Estimate (t-statistic)			
Intercept	0.4632	-7.4391	4.8973	-0.5473
	(0.0892)	(-1.4896)	(0.3711)	(-0.0449)
Savings	-0.6286	-1.8468	-0.5003	-1.6683
	(0.1787)	(-0.6086)	(-0.1423)	(-0.5495)
Income	15.0826**	8.3826	-0.3103	-14.8879
	(1.9699)	(1.2999)	(-0.0072)	(-0.3893)
Income^2			11.3678	16.9989
			(0.3637)	(0.6159)
Standard Dev.	21.5007***	18.8381***	21.3998***	18.6491***
of Error Term	(5.2670)	(5.5426)	(5.1841)	(5.5185)

*, **, *** Indicate 10%, 5%, and 1% significance.
Log Likelihood Function Value: -164.6706 (Uncalibrated 1) & -169.2157 (Calibrated 1)
Log Likelihood Function Value: -169.0268 (Uncalibrated 2) & -164.6049 (Calibrated 2)
Sample size is 278.

The first uncalibrated model finds the income variable to be significant at the 95% confidence level and suggests a positive influence on WTP. One should exercise caution, however, in this conclusion as it appears the estimator is assigning value to the income variable rather than the intercept. This is apparent as the intercept has become insignificant in this model, contrary to its previous significance. Nonetheless, this is the first sign of a significant coefficient outside the intercept and error terms. This estimation indicates that a crop producer, whose income exceeds $80,000, would be willing to pay approximately $15 more per acre for livestock manure.

When the model is calibrated, the income variable becomes insignificant. To confirm the model estimate, a LR test is conducted on the calibrated income variable. It fails to reject the hypothesis test (H_O: β_3=0 vs. H_A: $\beta_3 \neq 0$) with a *p*-value of 0.1718.

Realizing that a quadratic representation of income might better represent the marginal purchasing power of income, Uncalibrated and Calibrated models – 2 include a squared income variable and yield the following equation (reference group same as for Equation 16):

(17) $$WTP = \beta_1 + \beta_2[savings] + \beta_3[income] + \beta_4[income^2] + \varepsilon.$$

None of the parameter estimates is significant in the two models. A joint LR test for the two income variables in the calibrated model confirms the conclusion. The hypothesis of H_O: $\beta_3 = \beta_4 = 0$ vs. H_A: $\beta_3 \neq \beta_4 \neq 0$ does not reject the null with a p-value of 0.1341. Review of the last two models also suggests that total WTP for manure is $0. To confirm this observation, the researcher conducts the following hypothesis test on the Uncalibrated and Calibrated Models – 2: H_O: $\beta_2 = \beta_3 = \beta_4 = 0$ vs. H_A: $\beta_2 \neq \beta_3 \neq \beta_4 \neq 0$. The hypothesis test for the uncalibrated model is rejected with a p-value of 0.0299. However, the researcher fails to reject H_O with a p-value of 0.1134 on the calibrated model. This suggests to the researcher that despite the reduction in commercial fertilizer costs and other benefits, if crop producers are willing to pay for manure, the producers' income effect is very small, if any at all. Most likely, producers are willing to accept manure, but are unlikely to pay for it because they are aware of the regulations associated with using manure and that livestock producers hold a poorly demanded product.

Farm Size

Following producer income insignificance, the researcher tests for operation size significance. Like the income variables, the acres managed variable is categorized into five sections and then scaled by the largest category. This means that the values representing category size range from 0.2 to 1 (Refer to Table 3). Table 7 contains both calibrated and uncalibrated model estimates for the linear and quadratic acres variables.

Equations for the linear and quadratic models follow in respective order. Again, only *savings10* serves as the reference group.

(18) $$WTP = \beta_1 + \beta_2[savings] + \beta_3[acres] + \varepsilon.$$

(19) $$WTP = \beta_1 + \beta_2[savings] + \beta_3[\text{acres}] + \beta_4[acres^2] + \varepsilon.$$

Table 7. Impact of Farm Size on Willingness-to-Pay

	Uncalibrated Model - 1	**Calibrated Model - 1**	**Uncalibrated Model - 2**	**Calibrated Model - 2**
	Parameter Estimate (t-statistic)			
Intercept	9.5220**	-8.5629**	20.9978**	-4.4489
	(2.0661)	(-2.1087)	(2.3666)	(-0.5979)
Savings	1.0482	-0.6461	1.1231	-0.5797
	(0.3096)	(-0.2118)	(0.3305)	(-0.1903)
Acres	0.8019	13.1657*	-58.6397	-7.4168
	(0.1037)	(1.8808)	(-1.5535)	(-0.2310)
$Acres^2$			60.4284	20.5786
			(1.6102)	(0.6560)
Standard Dev. of Error Term	21.7648***	19.3576***	21.2756***	19.2612***
	(5.2823)	(5.5969)	(5.2940)	(5.6059)

*, **, *** Indicate 10%, 5%, and 1% significance.
Log Likelihood Function Value: -173.8585(Uncalibrated 1) & -176.3901 (Calibrated 1)
Log Likelihood Function Value: -172.4678 (Uncalibrated 2) & - 176.1740 (Calibrated 2)
Sample size is 287.

We observe in the first calibrated model that *acres* is significant at a 90% confidence level. The three other models yield no significant estimates for the *income* or *savings* variables. Given the results of the first set of models, the researcher believes that acre size may correlate with WTP, but the estimate is statistically weak at only a 90% confidence level. The second set of models does not identify a relationship between acre size and WTP and deems the estimates' signs and magnitudes insignificant. To confirm this, the following LR test is conducted on both models (2): H_O: $\beta_3 = \beta_4 = 0$ vs. H_A: $\beta_3 \neq \beta_4 \neq 0$. A joint LR test of the income variables for the uncalibrated model verifies the weak significance with a *p*-value of 0.0947 and the calibrated model yields a *p*-value of

0.0405. Collectively, the researcher concludes that acres managed as an explanatory variable does influence average WTP, but is weak. Thus, as the number of acres managed increases, so too does a crop producer's WTP. In summary, the linear models suggest WTP to be between \$4 and \$10. Quadratically, the WTP estimate ranges from \$0 to \$21. One would expect the WTP interval to narrow as a quadratic term for farm size is introduced, because a quadratic term allows for flexibility in the estimate to model a more realistic relationship that is non-linear.

<u>Regional Location</u>

Oklahoma consists of a number of different climates and topography. In this study, the state is divided into four quadrants using Interstates 35 and 40 as regional boundaries. A map of Oklahoma and the respective boundaries is located in the demographics section of Chapter 3. Provided the discussion in Chapter 3, one might suspect that the contrast of production practices could influence the WTP of producers in the regions. To test this theory, the following equation is estimated with *savings10* and *southeast* as the reference group.

(20) $WTP = \beta_1 + \beta_2[savings] + \beta_3[southwest] + \beta_4[northwest] + \beta_5[northeast] + \varepsilon.$

Estimates in Table 8 reveal that no region differs significantly from the southeast region. Although the signs and magnitudes of each variable provide no information about WTP, the intercepts again suggest that WTP ranges from approximately \$0 to about \$10. What this information does provide to producers is that despite a facilities' regional location, one is no more advantaged or disadvantaged in locating producers willing to accept/pay for livestock manure. One should consider however, that these regional climates and land topography will affect the rates of application because rainfall and land slope largely influence the potential for runoff and water pollution. This regional estimation cannot consider the environmental considerations that livestock producers are forced to consider before applying manure on off-farm acres. Despite its obscurity in this model, stricter regulations observed in the CAFO Rule may eventually create a regional affect on WTP that is not yet observable.

Table 8. Regional Influence on Willingness-to-Pay

	Uncalibrated Model	Calibrated Model
	Parameter Estimate (t-statistic)	
Intercept	8.9438*	0.5519
	(1.9048)	(0.1338)
Savings	0.6998	-0.4811
	(0.2085)	(-0.1669)
Southwest	-0.9093	-4.7129
	(-0.1792)	(-0.9766)
Northwest	0.4158	-2.0089
	(0.0810)	(-0.4137)
Northeast	4.5011	-3.5808
	(0.8062)	(-0.7489)
Standard Deviation of Error Term	21.2939***	19.7766***
	(6.1218)	(5.6178)

*, **, *** Indicate 10%, 5%, and 1% significance.
Log Likelihood Function Value: -174.3713 (Uncalibrated) and -178.2025 (Calibrated)
Sample size is 289.

Evidence from the previously discussed models exhibits little information to a concerned livestock producer about marketing alternatives. As the researcher has demonstrated, WTP is not affected by the numerous demographics and manure attributes measured in the survey. However, it is certain that WTP varies across crop producers. To reveal the probability that a crop producer will pay a given price, the next section focuses on the development of a cumulative distribution and its implications to livestock producers.

Distribution of Crop Producers' Willingness-to-Pay

Previous sections of the chapter focused on how particular variables affected the average WTP of crop producers. This section focuses on developing a distribution for WTP. In this process, the researcher estimates a cumulative distribution function (cdf) using both calibrated and uncalibrated data. The cdf is constructed as follows. Recall that the manure price could take one of 35 prices, ranging from -10, -9,…,-1, 1,…,24, to 25[14]. For each price appearing on the survey, the percentage of crop producers not accepting the offer is calculated to determine the percentage of producers declining the offer at each given price level. A regression analysis is then employed to estimate the correlation between the percentage of producers declining the offer and the respective price offered. With the percentage of producers declining the offer serving as the dependent variable, Excel's regression analysis option is used to estimate the relationship both linearly and quadratically. This linear relationship is expressed with the following model:

$$\%No = \beta_1 + \beta_2[P] \qquad (21)$$

Intuitively, if $\beta_1 + \beta_2[\$0] = 35\%$, then the WTP for 35% of producers is less than \$0 and WTP for 65% exceeds \$0. Conducting these estimates across all prices, allows the researcher to determine a cumulative distribution for crop producers' WTP and the subsequent probability distribution function.

[14]The price of \$0 was not presented in the survey, and therefore that category is not present in the data set used for estimation.

Uncalibrated Willingness-to-Pay Distribution

The first cumulative distribution functions are estimated using uncalibrated data. One should note that results generated by the uncalibrated data set may be subject to bias as "uncertain" respondents are not calibrated as "No" responses. Contrary to previous uncalibrated models, producers who answered, "No Answer" are not considered an observation. Therefore, the sample size is only 236.

The first linear regression model has an adjusted r-square of 0.3995, which suggests that almost 40% of crop producers' WTP is explained by the price offered. The regression generates the following model.

$$\%\text{No} = \underset{(3.2613)}{0.1799} + \underset{(4.8597)}{0.0206}\,[P] \tag{22}$$

where the numbers in parentheses represent the coefficients' *t*-statistics.

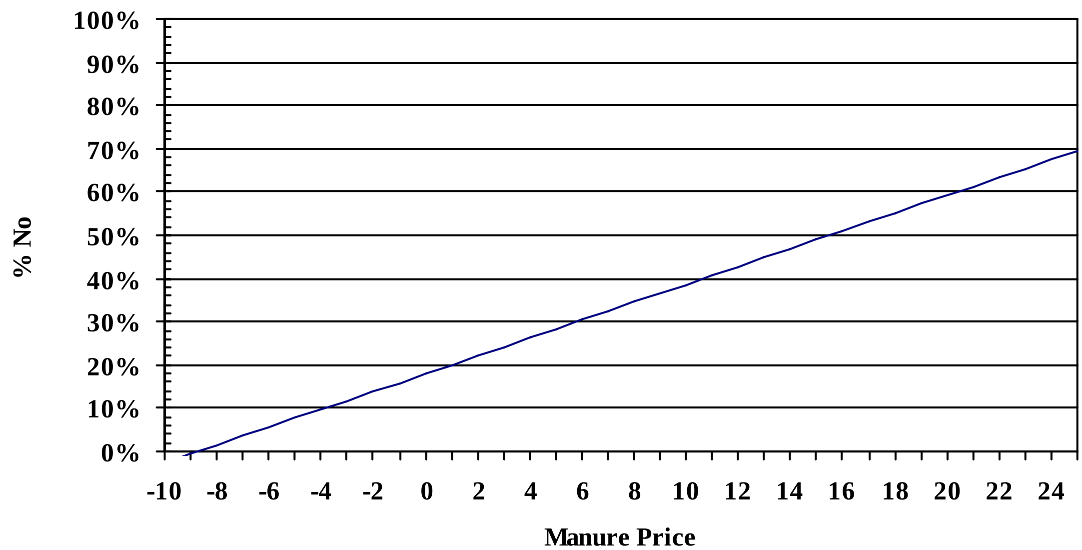

Figure 14. Percent of Crop Producers Declining Offer (Assumption Set A)

The model suggests that as a producer is asked to pay a higher price for manure, the percentage of producers declining the offer increases. This coincides with demand theory, such that as price increases, demand decreases. To allow for a non-linear cdf, a quadratic price term is included in the next estimation.

$$\%No = \beta_1 + \beta_2[P] + \beta_3[P^2] \tag{23}$$

Interpretation of the quadratic model's cumulative distribution remains the same as applied to the linear model. The quadratic model yields slightly different results and produces an adjusted r-square of 0.4293.

$$\underset{(2.3835)}{\%\text{No} = 0.1403} + \underset{(1.2431)}{0.0097[P]} + \underset{(1.6501)}{0.0007[P_i^2]} \tag{24}$$

The two price terms are not significant at 95% confidence, but a joint *f*-test of the variables (H_O: $\beta_2 = \beta_3 = 0$ and H_A: $\beta_2 \neq \beta_3 \neq 0$) yields an *f*-statistic[15] of 13.7861, exceeding the 5% critical value of 3.295 and rejecting H_O. By jointly testing for significance, we find that the effect observed in the estimation is indeed different from zero, despite the lack of significance for each term, individually.

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[15] The general *f*-statistic is given by the following equation. $F = \frac{(SSE_R - SSE_U)/J}{SSE_U/(T-K)}$ where SSE_R represents the sum of squared errors for the restricted model, SSE_U is the sum of squared errors for the unrestricted model, J is the number of hypotheses, T is the number of observations, and K is the number of coefficients estimated in the model.

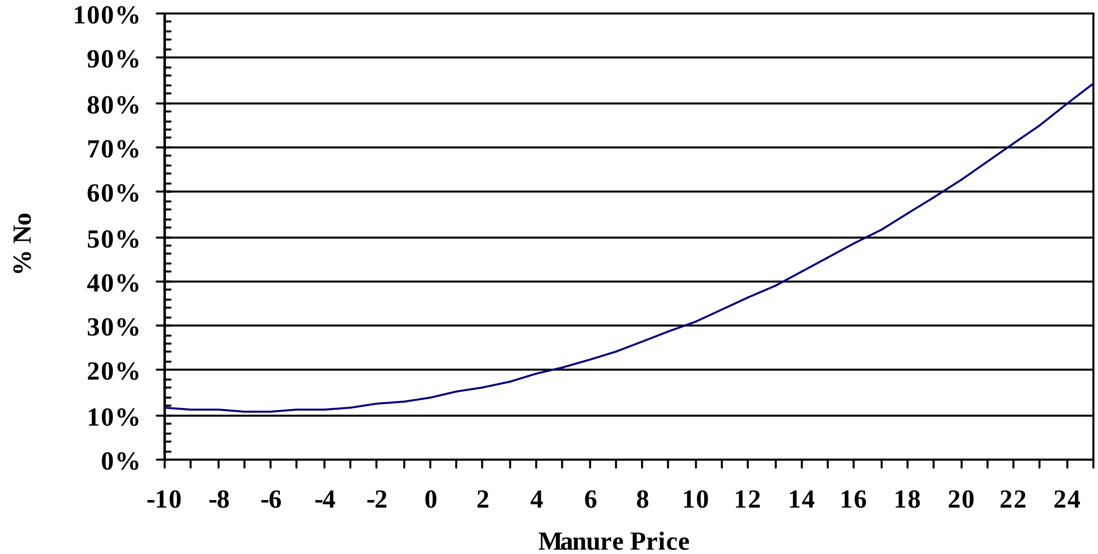

Figure 15. Percent of Crop Producers Declining Offer (Assumption Set B)

In Figure 15, we note a couple of things differ from the linear estimate. First, note how this model's intercept is greater than zero. This indicates that despite being paid $10 an acre to accept manure, there remains the probability that a producer will not accept the manure. The model also suggests a strong relationship between the offer price and the percentage of acceptance. Another interesting observation about this model is the signs observed for the linear and quadratic price terms. Both signs are positive suggesting that as the price of manure increases, the percentage of declining producers accelerates at a greater rate. For instance, let us compare the decreasing rate of acceptance between the linear and quadratic models. For the linear model, the decreasing rate of acceptance is constant at 10% across each $5 interval. For example, at the price of $-5, the rate of acceptance is 92%, at $0 it is 82%, and so forth. However, for the quadratic model, at the price of $-5, acceptance is 89%. Across the next interval, acceptance declines to 86%, a difference of only 3%. From $15 to $20, acceptance declines from 55% to only 37% (18% decrease).

If we consider that the percentage of declining producers also represents the substitutability of livestock manure for commercial fertilizer, then one can infer about the willingness to substitute between livestock manure and commercial fertilizer. When the price is negative, the marginal rate of substitution is high. This suggests that if crop producers are compensated, manure's substitutability with commercial fertilizer is high. As the price begins to increase, the marginal rate of substitution quickly begins to decline to the point at which manure is virtually not substitutable with commercial fertilizer.

In the next section, the researcher calibrates the data to recode "uncertain Yes" and "No Answer" responses to "No" responses and measure the effects on the cumulative distribution of crop producers.

Calibrated Willingness-to-Pay Distribution

In this data set, the researcher used the calibrated data adjusted for crop producers uncertain in their decision and those who declined to answer the question for a number of reasons. Collectively, interpretation of estimates and the implications will be the same as in the previous section. The linear model estimate using calibrated data yielded the following equation with an adjusted r-square of 0.4297:

$$\%\text{No} = \underset{(11.1273)}{0.5151} + \underset{(5.1588)}{0.0184}\,[P] \tag{25}$$

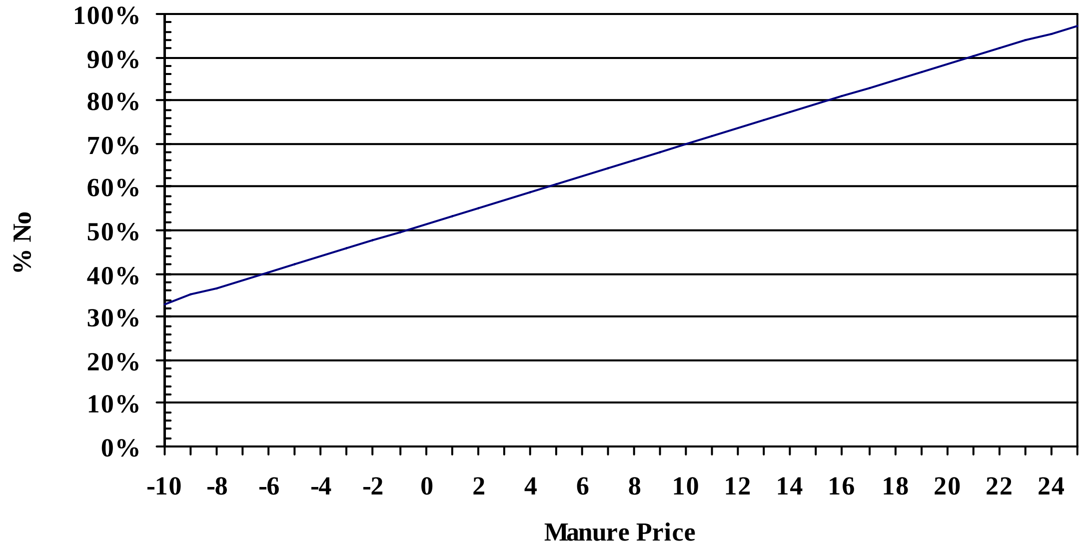

Figure 16. Percent of Crop Producers Declining Offer (Assumption Set C)

Reviewing these results, the first observation about this model is the increased number of respondents declining the offer. In comparison to both the linear and quadratic models in the previous section, the percentage of respondents declining the offer is significantly higher. This puts into context the consequential effects of hypothetical bias if it is not considered. In this instance, the percentage of producers accepting manure at a price of $-10, went from 100% in the uncalibrated model to only 70% in the calibrated model. Even the uncalibrated quadratic model, which estimated 12% of crop producers would decline application at $-10, was well below the 33% of this model. Notice also that at the price of $25 per acre, less than 3% of producers are predicted to have an average WTP that exceeds that value.

Now let us look at the quadratic cumulative distribution model for WTP. Equation 26 provides the coefficient estimates and respective *t*-statistics.

$$\%\text{No} = \underset{(10.0054)}{0.5149} + \underset{(2.6878)}{0.0183}[P] + \underset{(0.0059)}{0.00002}[P^2] \tag{26}$$

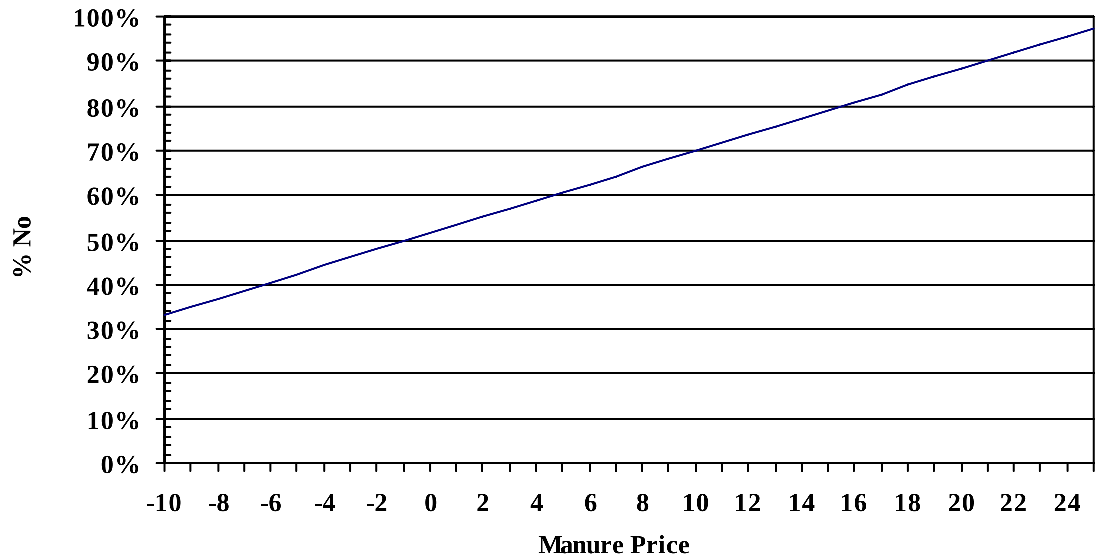

Figure 17. Percent of Crop Producers Declining Offer (Assumption Set D)

The first thing to notice is that despite being quadratic, the model appears linear. Upon review of the coefficient estimates, the *price*^{2} term is insignificant and the *intercept* and *income* variables are only fractionally different from the linear estimates. This model actually produces a marginally weaker adjusted r-square of 0.4118. The linear depiction of the model despite being quadratic suggests to the researcher that the probability distribution function for crop producers' WTP may be uniform.

Reviewing the four models, the obvious trend is that producer purchases decline as the price increases. However, the estimated percentage of decline was quite different across the model estimates. To better articulate the results from the four models, the researcher creates a table that documents the offer price and the predicted cumulative percentage of crop producers' declining the offer. One of most prominent observations is how calibrating the data increases the percentage of respondents declining the offer at $-10. We also note that at $25 in the calibrated models, only a very small percentage of producers would accept manure. In general, the calibrated models depict a more disappointing outlook for producers seeking off-farm acres for manure spreading. Despite the reduced acceptance rates predicted by the calibrated models, almost 50% of crop producers are willing to pay a price above $0.

Table 9. Cumulative Percent of Producers Declining Offer

Price	Uncalibrated Model *N = 236*		Calibrated Model *N = 289*	
	Linear	Quadratic	Linear	Quadratic
$-10	0.0%	11.7%	33.1%	33.2%
$-5	7.7%	11.0%	42.3%	42.3%
$0	18.0%	14.0%	51.5%	51.5%
$5	28.3%	20.7%	60.7%	60.7%
$10	38.6%	31.1%	69.9%	69.9%
$15	48.9%	45.1%	79.1%	79.1%
$20	59.2%	62.8%	88.3%	88.3%
$25	69.6%	84.1%	97.4%	97.5%

Summary

In summary, this study has found that a crop producer's decision to purchase manure is largely driven by the price. Outside price, few manure attributes and producer demographics are found to significantly correlate with purchasing behavior under the assumptions of a normal WTP distribution and random utility theory. This raises the question that if producers are inconsiderate of other manure attributes, outside price, can the contingent valuation results be validated? As noted by Carson in the literature review, estimates of unbiased studies should follow basic demand theory in terms of price sensitivity and satisfy scope tests, where consumers recognize and pay a difference for greater quality. Should producers then be willing to pay more for manure that increases commercial fertilizer savings by means of more nutrients, suggesting a higher quality product? This may be the case, but Carson also notes that alternative estimation procedures should be employed. This could include anything from the estimation procedure to assuming a skewed rather than normal distribution of willingness-to-pay. Before the results of this study can be discounted, alternative methods must be sought. Unfortunately, time and scope do not allow us to answer these questions at this time. Therefore, we must move forward with the results of this study at this place in time.

Results suggest that income and farm size may have some effect on a crop producers' WTP, but the inconsistency of the variables across several models reduces the reliability of the estimates. The lack of explanatory power for WTP with the given variables is somewhat surprising. One suspects there is the possibility that producers are making decisions from unmeasured variables such as commercial fertilizer cost per acre, percentage of total operating costs assigned to commercial fertilizer, or purpose of the agricultural operation (e.g. tax write-off, hobby, or primary income) (Other potential components of manure demand are discussed at the end of Chapter 2.). Additionally, producers may be influenced by the perceived consequences of manure use on crops such as weeds, foreign matter, soil compaction, etc. Certainly, WTP varies greatly across crop producers. At negative prices, a majority of crop producers will accept manure. However, as price increases, so do the number of crop producers declining the offer. The key for livestock producers to optimize income from manure exportation will be to identify the threshold value for each individual crop producer.

Even with the lack of explanatory variables, the survey results do offer hope for livestock producers by revealing that an outlet for livestock manure exists for producers falling under federal compliance and seeking additional land. Both the linear and quadratic regression models suggest that a high percentage of crop producers are willing to accept manure when the cost is \$0. The key to developing a market sensitive to product attributes and paying a price exceeding $0 may become a matter of consumer (crop producer) education and greater marketing efforts. As more livestock operations become compliant with regulations and spread manure to surrounding cropland, a similar survey in the future could hold a significantly greater degree of explanatory power for crop producers' purchasing decisions of livestock manure.

SUMMARY AND CONCLUSIONS

Almost two years after the EPA's final rule regulating CAFOs became effective, livestock producers continue to become compliant and explore alternatives to offset the incurring costs. In light of the predicament that many livestock producers were experiencing, it became apparent to the researcher that more information was needed to enlighten livestock producers and researchers assessing the economic impacts of these regulations. As the final rule requires all CAFOs to apply for a National Pollution Discharge Elimination System permit and implement a Comprehensive Nutrient Management Plan by the end of 2006, the regulations limit the flexibility in manure application for livestock producers (Boman). This subsequently increases expenses for livestock producers. The EPA admits that the final rule will be expensive, carrying a price tag of $335 million a year. However, the EPA's objective is to work with the agricultural industry to control water pollution from the largest livestock operations, while simultaneously maintaining a strong and viable American agriculture (USEPA).

Recognizing a shortage of information existed in academic research on this topic and a need for specific costs beyond an aggregate cost estimate for the industry, the researcher sought to reveal crop producers' manure preferences in regard to attributes and demographics. The absence of a functional and observable market for manure limited previous studies that employed traditional valuation approaches in determining what factors were important to crop producers in their decision to accept livestock manure as a commercial fertilizer substitute. This predicament prompted the use of contingent valuation and random utility theory to determine decision factors influencing crop producers' purchases of manure in a hypothetical market.

Recall the study's two objectives: (1) determine correlation of crop producers' willingness-to-pay with manure attributes and producer demographics, and (2) identify a willingness-to-pay distribution for crop producers accepting livestock manure. To obtain the data necessary to complete such a study, a contingent valuation survey is employed. Few transactions occur between crop and livestock producers for manure, and those that do are poorly documented. Therefore, a hypothetical market administered through a mail survey provided the hypothetical transactions for data collection.

The survey gathers information from producers across the State of Oklahoma who previously indicated a willingness to participate in university research projects. This generates 289 useful survey responses measuring numerous variables, including farm size, manure preferences, crops managed, household income, and livestock managed.

In satisfying the objectives, the first is partially satisfied as variables are summarized for the entire sample. Summary statistics from the survey reveal several behaviors about crop producers. First is that Oklahoma's crop producers are diversified across livestock and crop industries. Over 92% of the surveyed crop producers manage a cow-calf operation, stockers, or both. As expected, the primary crop grown in Oklahoma is wheat, with at least 89% of respondents involved with wheat production at some capacity (i.e. grain, grazing, or dual). The average number of acres managed by each respondent is 2,178 acres with an average household income of $68,870.

Producers also indicated a number of manure preferences outside the context of the contingent valuation question. Approximately 46% of producers would prefer manure incorporation at the time of application, but a large percentage (38%) does not have a preference. The most common timing restriction that producers indicated for application is for spreading to take place after harvest and prior to planting. For many livestock producers, this would impose an even smaller window to remove waste from the operation. 55% of producers did not express a preference for solid or liquid manure, and less than 25% of producers have any experience with manure as a commercial fertilizer substitute in the last ten years.

Satisfying the second part of the first objective includes constructing several models to reveal the correlation between crop producers' WTP and specific manure attributes and demographics. To minimize the impacts that hypothetical bias can have on estimation procedures, both calibration and cheap talk techniques are employed. All observations are influenced by the cheap talk mechanism that precedes the contingent valuation question. This helps to reduce respondents' natural tendency to overstate WTP. Calibration is also employed to reduce the likelihood of hypothetical bias. Changing "No Answer" and uncertain "Yes" responses to "No," creates a data set biased toward underestimating the average WTP of crop producers. Likewise, the uncalibrated data set should be biased toward overestimating average WTP. As explained in the previous chapters, this creates an interval in which the true value for WTP should be observed.

A large percentage of the explanatory variables were insignificant in explaining the willingness-to-pay of crop producers. Differences in the type of livestock manure, the physical form of manure (liquid or solid), and whether manure was incorporated or not fails to influence crop producers' WTP. However, a joint likelihood test confirms that the effect of *dryswine, liquidswine, experience,* and *incorporation* collectively differ from zero, but the individual impact of each variable is undetectable. Even more surprising is that producers do not express a difference in value for the levels of savings (nutrient content) in commercial fertilizer costs. This indicates to the researcher that crop producers willing to pay for manure are not likely to pay the manure's full nutrient value. Crop producers' income did appear to influence the WTP of crop producers. In the linear estimate, income positively influenced WTP. However, calibrated models contradicted this observation by failing to distinguish a significant relationship. Given the assumed bounds that the calibrated and uncalibrated models determine, the effect of income is assumed to be marginal.

Farm size is the only variable found to be significant across both calibrated and uncalibrated models. Under a linear estimation, the calibrated model indicated a $13 increase in WTP for producers whose acres managed exceeded 10,000 acres. Quadratic estimates found neither *acres* coefficient (linear and quadratic *acres* variables) to be significant, but a joint likelihood ratio test indicates collective significance for the variables at 90% for the uncalibrated model and 95% for the calibrated model. This confirms that a measurable correlation exists between crop producers' farm size and their WTP value. Thus, as the number of acres managed by a crop producer increases, so does her value for livestock manure.

The last variable tested for significance was regional location. Despite the divergence between management practices observed in different regions of the state, WTP is not affected. This does not go without saying however, that nutrient management plans are largely affected by soil types, slope of the land, annual average rainfall, crop-nutrient requirements, and proximity to surface waters. Given these factors, there is no question that livestock producers in different regions will face a different set of circumstances. Therefore, crop producers likely face challenges in not only locating a producer willing to accept manure application, but one whose land and crop characteristics satisfy the restraints of their own nutrient management plan. The positive aspect is that, in general, the models suggest that the average WTP value is between $0 and $10. In some instances, that range was expanded to $15 and $21, but consistent estimates appear to be between $0 and $10. Additionally, this suggests that livestock producers "on average" will not have to pay crop producers to accept manure on off-farm acres. Some livestock producers may have to pay for manure removal, but across a large sample of crop producers, most crop producers will accept manure and some will even pay a price less than or equal to its nutrient value.

The second objective is satisfied by developing a cumulative distribution function for all crop producers' WTP. Recall that for each price appearing on the survey, the number of crop producers not accepting the offer is calculated to determine the percentage of producers declining the offer at each given price level (-10, -9, …, -1, 1, …, 24, 25). Linear and non-linear regressions estimate the probability that a crop producer would decline the offer. Uncalibrated regression estimates suggest that approximately 86% of crop producers would pay a price above $0 and 14% of crop producers' WTP would be less than $0. One should add a caveat about the percentage of producers accepting manure application at the price of $0. There may be an unforeseen spike in the percentage of producers declining on the positive side of zero as the concept of "free" manure changes to a positive price. Nonetheless, estimates should not be greatly affected by this anomaly. Calibrated estimates find that the split is almost 50%-50% at $0, suggesting that half of producers' WTP is greater than $0 and half is not. Provided these results, the actual percentage of crop producers willing to pay a price greater than $0 an acre is between 50% and 86%.

Collectively, results suggest that manure price is the major determinant in a crop producers' decision to purchase. However, other explanatory variables such as the type and form of manure, management practices, income, etc., appear to reveal little information about an individual producer's purchasing decision. Because of the heterogeneity expressed across producers' decision components, livestock producers may be advantaged by identifying only a few specific crop producers that are willing to accept manure. Strong relationships could be established where prices and manure characteristics are negotiated prior to application. This could alleviate search costs and the hassle of differentiating a manure product to be acceptable for the entire market.

Nonetheless, overcoming the obstacles identified in this market must be accomplished by addressing the nutrient variation in manure, the inappropriate ratio of nitrogen and phosphorus to crop needs, and the higher application costs of diluted nutrients. There is no question that manure management problems exist. Regionally concentrated areas of livestock production have created stocks of manure that exceed the assimilative capacity of regional cropland. Though this is of concern to livestock producers, this study has revealed that at a minimum, 50% of crop producers are willing to accept manure for free. More encouraging is the fact that many crop producers are willing to pay a positive price.

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APPENDIX

Appendix I. Oklahoma Crop Producer Survey Instrument

OKLAHOMA STATE UNIVERSITY
Division of Agricultural and Natural Resources
Department of Agricultural Economics

October 8, 2003

Jane Doe
P. O. Box 7448
Manure, OK 58837

Dear Jane Doe:

New government regulations are changing how livestock manure must be handled. In particular, livestock producers may seek other farmers who are willing to accept their manure as fertilizer. Researchers at Oklahoma State University are evaluating strategies to minimize the impacts of these regulations to Oklahoma farms. **We are asking you to help us serve the Oklahoma farm community by completing the enclosed survey**. The survey should take approximately five minutes to complete.

We would like the person who is most responsible for farm management on your operation to complete the enclosed survey. Your responses will be kept strictly confidential by recording them using an identification number that reveals neither your name nor the farm location.

Please return your completed survey to us in the enclosed postage paid envelope by December 10. If you have any questions regarding this survey, please call me at (405) 744-9820, and I will be happy to assist you.

We greatly appreciate your help.

Sincerely,

F. Bailey Norwood
Assistant Professor
Oklahoma State University

OKLAHOMA STATE UNIVERSITY
Division of Agricultural and Natural Resources
Department of Agricultural Economics

YOUR RESPONSE IS VALUABLE TO US. FOR THE FOLLOWING QUESTIONS, PLEASE CHECK THE BOXES THAT BEST CORRESPOND TO YOUR OPERATION.

1) Please check any of the following you manage.

- ☐ Winter wheat for grain
- ☐ Winter wheat for grazing
- ☐ Winter wheat for grazing & grain
- ☐ Corn for grain
- ☐ Corn for silage
- ☐ Grain sorghum
- ☐ Soybeans
- ☐ Alfalfa hay
- ☐ Other hay
- ☐ Pasture
- ☐ Cotton
- ☐ Oats
- ☐ Barley
- ☐ Rye
- ☐ Peanuts
- ☐ Other (please specify) ____________

2) How many crop or pasture acres do you currently manage?

- ☐ 0-499 acres
- ☐ 500-999 acres
- ☐ 1,000-2,999 acres
- ☐ 3,000-9,999 acres
- ☐ Greater than 10,000 acres

3) Please check any of the following livestock you manage.

- ☐ Cow/calf
- ☐ Stockers
- ☐ Cattle on feed
- ☐ Dairy cattle
- ☐ Broilers
- ☐ Other poultry
- ☐ Swine
- ☐ Sheep
- ☐ Other (please specify): ___________

4) Has livestock manure been applied to any crop or pasture acres you managed in the last ten years?

- ☐ No
- ☐ Yes

5) Livestock manure can be applied as solid manure or liquid manure. Assuming the costs to you were the same, if you allowed livestock manure applications to crop acres under your management, which manure form would you prefer?

- ☐ I prefer solid manure
- ☐ I prefer liquid manure
- ☐ No preference

6) Livestock manure can be incorporated into the soil by either tilling the soil after surface application or through manure injection. Assuming the costs to you were the same, if you allowed livestock manure applications to crop acres under your management, would you prefer soil incorporation?

- ☐ I would not prefer soil incorporation of manure
- ☐ I would prefer soil incorporation of manure
- ☐ No preference

In the next question, we would like you to tell us how you feel about substituting livestock manure for commercial fertilizer. Studies have found that people tend to overestimate their willingness to accept or pay money in hypothetical situations. When answering the question, please consider how you would react if you actually had to pay or accept real money that could be used for other goods and services.

7) Suppose your crop has traditionally received commercial fertilizer but no livestock manure. You now have the opportunity to let a nearby producer apply swine manure to your crop. With the swine manure application, you would not need to apply commercial fertilizer and would save $20 per acre in commercial fertilizer costs. The manure is of the liquid form and is incorporated into the soil.

If the livestock producer offered to pay you $6 per acre to apply manure to your crop, would you accept the offer?

☐ Yes ☐ No ☐ No Answer

8) **If you checked "No Answer"** to the previous question, was this because?

- ☐ Rough indifference between a "yes" or "no" answer
- ☐ Inability to make a decision without more information
- ☐ Preference for some other mechanism for making this decision
- ☐ Other (please explain)

9) If you checked "Yes" to Question 7, on a scale of 1 to 10, where 1 means "very uncertain" and 10 means "very certain," how certain are you that you would accept $6 per acre for the manure application, if actually given the opportunity? (CIRCLE ONE NUMBER)

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
very uncertain									very certain

10) If you allowed livestock manure applications to crop acres under your management, what restrictions would you place on the timing of manure applications?

- ☐ I prefer applications after harvest and prior to planting
- ☐ I prefer applications during the growing season as long as it does not interfere with crop growth
- ☐ I would not place any restrictions on when manure can be applied
- ☐ Other

11) As close as you can recall, please estimate your household's yearly income before taxes by checking the appropriate box. This question is used to ensure our sample is representative of all Oklahoma producers. Please remember that your responses will be held strictly confidential.

☐ less than $20,000 ☐ $20,000-$39,999 ☐ $40,000-$59,999 ☐ $60,000-$79,999 ☐ $80,000 or greater

12) Do you have any additional comments about animal manure applications to your crops or pastures? If so, please list them below.

On behalf of Oklahoma State University, we thank you for your response!

Bailey Norwood, Assistant Professor
College of Agriculture Sciences and Natural Resources
Oklahoma State University

VITA

Ryan Lee Luter

Candidate for the Degree of

Master of Science

Thesis: OKLAHOMA CROP PRODUCERS' WILLINGNESS-TO-PAY FOR LIVESTOCK MANURE: A CONTINGENT VALUATION APPROACH

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Stillwater, Oklahoma on July 16, 1980, the son of Dannie L. and Patty J. Luter

Education: Graduated from Morrison High School, Morrison, Oklahoma in May 1999; Received Bachelor of Science degree in Agribusiness with minors in finance and business administration from Oklahoma State University, Stillwater, Oklahoma in May 2003. Completed the requirements for the Master of Science degree with a Major in Agricultural Economics at Oklahoma State University in May 2005.

Experience: Research Honor Scholar, Department of Agricultural Economics, August 1999 to May 2000; Biological Assistant Agricultural Research Service, USDA, April 2000 to September 2000; Sales Representative Intern, Range and Pasture Division, Dow AgroSciences, June 2001 to August 2001; Summer Loan Officer, Farm Credit Services of Eastern Oklahoma, U.S. AgBank, FCB, June 2002 to August 2002; Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, May 2003 to May 2005.

Professional Memberships: American Agricultural Economics Association; Agricultural Economics Graduate Student Association, Oklahoma State University

Name: Ryan L. Luter Date of Degree: May 2005

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: OKLAHOMA CROP PRODUCERS' WILLINGNESS-TO-PAY FOR LIVESTOCK MANURE: A CONTINGENT VALUATION APPROACH

Pages in Study: 128 Candidate for the Degree of Master of Science

Major Field: Agricultural Economics

Scope and Method of Study: The Environmental Protection Agency's final rule revising the Clean Water Act in 2003 may force many livestock and poultry producers to seek off-farm acres to spread manure. The impact of these regulations on confined animal feeding operations depends on crop producers' willingness-to-pay for manure. Contingent valuation surveys, mailed to 512 Oklahoma crop producers, were used to determine the willingness-to-pay of crop producers.

Findings and Conclusions: Numerous producer preferences for manure are examined in estimating Oklahoma crop producers' average willingness-to-pay for livestock manure. Crop producer income and farm size are shown to be correlated with willingness-to-pay. Willingness-to-pay is not influenced by regional location in Oklahoma, livestock manure type, physical manure state (solid or liquid), or savings in commercial fertilizer costs. Models suggest that the average willingness-to-pay for manure by crop producers is between $0 and $15 per acre. Cumulative distributions of crop producers' willingness-to-pay suggest a market does exist for livestock producers seeking to export manure. Conservative estimates reveal that approximately 50% of crop producers are willing to accept manure when it is applied and offered at the price of $0 per acre.

ADVISER'S APPROVAL: ______________________________